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**FISHERIES INVENTORY AND IMPACT ASSESSMENT
IN RELATION TO THE PROPOSED MURPHY CREEK PROJECT
ON THE COLUMBIA RIVER, B.C.
MAIN REPORT
AND
MURPHY CREEK PROJECT FISHERIES STUDY
SUMMER/FALL 1981 STUDIES
ADDENDUM**

Prepared for
B.C. Hydro
Vancouver, British Columbia

by
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Edmonton, Alberta

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**FISHERIES INVENTORY AND IMPACT ASSESSMENT
IN RELATION TO THE PROPOSED MURPHY CREEK
PROJECT ON THE COLUMBIA RIVER, B.C.**

Main Report

Prepared for

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November 1981

(Revised January 1984)

B.C. HYDRO

This impact assessment is based on the "Murphy Creek Project Engineering Description" prepared in November 1982. Since that time, ongoing planning and design studies have resulted in some changes that would affect the project description. The principal changes are as follows:

- In-service date has changed from 1993 to 1995.
- Installed capacity has changed from 300 MW to 275 MW.
- Small changes to the design and locations of shoreline protective works.
- Daily reservoir level fluctuations limited to 2.0 m during March, April and May (previously March and April).

The above changes have been incorporated in the report only where they would affect the results of the impact assessment.

PREFACE

This document is composed of two reports on studies conducted during 1980 and 1981 as part of the detailed environmental and socio-economic studies for the proposed Murphy-Creek Project. The first report, entitled "Fisheries inventory and impact assessment in relation to the proposed Murphy Creek Project on the Columbia River, B.C.", contains the fisheries inventory information collected during 1980 and the spring of 1981, with a discussion of the potential impacts of the proposed development, and mitigation opportunities that exist to reduce the impact of the development. The second report, entitled "Murphy Creek fisheries study addendum report - summer/fall 1981 studies" presents and discusses the results of an additional study conducted 15 August to 6 September 1981 to identify and document upstream migrations of kokanee past the proposed damsite, and to document the extent of kokanee spawning within tributaries to the proposed reservoir.

This document was submitted in draft form to B.C. Hydro in November 1981, and was reprinted with minor revisions in April 1982. It subsequently was submitted to government agencies for review, and a revised document was produced in November 1982 incorporating appropriate suggestions or change resulting from comments received, and changes reflecting an updated project description. The present document represents further revisions as a result of comments received from B.C. Hydro in December 1983, and reflects the updated project engineering description for the Murphy Creek Project prepared by the Hydroelectric Generation Projects Division of B.C. Hydro in November 1982 (B.C. Hydro 1982).

A number of additional aquatic studies relating to the potential hydroelectric development of the lower Columbia River in British Columbia have been initiated by B.C. Hydro since the preparation of the original draft of this report. In March of 1982, R.L. & L. Environmental Services Ltd. was contracted to review existing information and assess the probable impacts on the fisheries resources of the incorporation of generating facilities in the Hugh Keenleyside Dam in conjunction with the Murphy Creek Project. This study was reported in a document entitled "Fisheries inventory and impact

assessment for the proposed Keenleyside Powerplant Project on the Columbia River, B.C." dated May 1982 (revised January 1984). Other aquatic studies that have been conducted or are presently being conducted include the following:

- 1) a water quality and aquatic resource study to collect additional baseline information in the Columbia River between the Hugh Keenleyside Dam and Trail (conducted by R.L. & L. Environmental Services Ltd. during 1982-1984);
- 2) angler use and fish harvest studies on the Columbia River (conducted by B.C. Fish and Wildlife Branch during 1980-1982; summary report produced in 1983);
- 3) a study to monitor fish entrainment at the Hugh Keenleyside Dam (conducted jointly by B.C. Hydro and R.L. & L. Environmental Services Ltd. during 1983-1984); and
- 4) a detailed water quality study of the Columbia River below the Hugh Keenleyside Dam (conducted by B.C. Hydro 1983-1984).

January 1984

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The following employees of R.L. & L. Environmental Services Ltd. contributed to the collection of data and preparation of the report:

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	v
LIST OF FIGURES	vii
LIST OF APPENDICES	ix
SUMMARY	xi
1.0 INTRODUCTION	1
1.1 BACKGROUND	1
1.2 STUDY AREA	1
1.3 STUDY OBJECTIVES	4
2.0 METHDOLOGY	5
2.1 STUDY SCHEDULING	5
2.2 SOURCES OF BACKGROUND INFORMATION	5
2.3 LOGISTICS	5
2.4 SAMPLING SECITONS	6
2.5 FISH COLLECTION TECHNIQUES	6
2.5.1 Boat Electrofishing	6
2.5.2 Backpack Electrofishing	9
2.5.3 Gillnetting	10
2.5.4 Fish Trapping	11
2.5.5 Beach Seining	12
2.5.6 Set Lines	13
2.5.7 Float Surveys	13
2.6 LOCATION OF SPAWNING AREAS	13
2.6.1 Escapement Estimates	14
2.7 MYSID SAMPLING	14
2.8 FISH MARKING	14
2.9 FISH LIFE HISTORY DATA	15
2.9.1 Collection Phase	15
2.9.2 Analysis Phase	15
2.10 HABITAT SURVEYS	16
3.0 INVENTORY OF AQUATIC RESOURCES	17
3.1 GENERAL LIMNOLOGY	17

	<u>Page</u>
3.1.1 Water Quality	17
3.1.2 Benthic Invertebrates	29
3.1.3 Mysids	32
3.2 FISH SPECIES COMPOSITION AND STATUS	34
3.3 MAJOR SPORT FISH SPECIES	38
3.3.1 Kokanee	38
3.3.2 Rainbow Trout	60
3.3.3 Dolly Varden	79
3.3.4 Mountain Whitefish	82
3.3.5 Burbot	86
3.4 MINOR SPORT SPECIES	91
3.4.1 White Sturgeon	91
3.4.2 Walleye	94
3.4.3 Brook Trout	96
3.4.4 Lake Whitefish	97
3.4.5 Chinook Salmon	97
3.5 NON-SPORT SPECIES	98
3.5.1 Peamouth	98
3.5.2 Northern Squawfish	99
3.5.3 Suckers	100
3.5.4 Carp	103
3.5.5 Redside Shiner	104
3.5.6 Sculpins	105
3.5.7 Longnose Dace	106
3.6 HABITAT DESCRIPTION	106
3.6.1 Mainstem Columbia River	106
3.6.2 Kootenay River	112
3.6.3 Other Tributary Streams	114
3.7 RESOURCE USE	169
4.0 EFFECTS OF DEVELOPMENT	175
4.1 PROJECT DESCRIPTION	175
4.2 DESIGN AND PRE-CONSTRUCTION PHASE	179
4.3 CONSTRUCTION PHASE	180

	<u>Page</u>
4.3.1 Blockage of Fish Migrations	181
4.3.2 Decreased Water Quality	181
4.3.3 Reduced Streamflow	183
4.3.4 Increased Angling Pressure	184
4.3.5 Use of Explosives	185
4.3.6 Construction of Ancillary Facilities, and Highway/ Railroad Construction	185
4.4 OPERATIONAL PHASE	186
4.4.1 Blockage of Fish Migrations	187
4.4.2 Loss of Riverine Habitat	191
4.4.3 Loss of Spawning Habitat	191
4.4.4 Loss of Rearing Habitat	195
4.4.5 Murphy Creek Reservoir	195
4.4.6 Reservoir Fish Species Composition and Abundance	204
4.4.7 Downstream Effects	216
5.0 MITIGATION AND COMPENSATION OPPORTUNITIES	219
5.1 CONSTRUCTION PHASE	219
5.1.1 Blockage of Migrations	219
5.1.2 Sediment Loads	219
5.1.3 Water Quality	220
5.1.4 Use of Explosives	220
5.1.5 Reservoir Clearing	221
5.1.6 Increased Angling	221
5.1.7 Timing of Reservoir Filling	221
5.2 OPERATIONAL PHASE	221
5.2.1 Blockage of Fish Migrations	221
5.2.2 Provision of Cover	225
5.2.3 Rate of Drawdown (Operating Regime 1)	225
5.2.4 Headpond Level Fluctuations	226
5.2.5 Releases from the Hugh Keenleyside Dam	226
5.2.6 Enhancement Opportunities for the Murphy Creek Reservoir	227

	<u>Page</u>
5.2.7 Construction of Fish Passage Facilities at Natural Obstructions	230
5.2.8 Instream Improvements	231
5.3 ENHANCEMENT OUTSIDE OF THE IMMEDIATE STUDY AREA	231
6.0 DATA GAPS AND RECOMMENDATIONS FOR FURTHER STUDY	233
6.1 SUPERSATURATION OF DISSOLVED GASES	233
6.2 IMPORTANCE OF MYSIS RELICTA IN THE STUDY AREA ..	233
6.3 KOKANEE STOCKS	234
6.4 SPORT FISH MOVEMENTS PAST THE DAMSITE	234
6.5 EXTENT OF RECRUITMENT FROM ARROW LAKES RESERVOIR	235
6.6 POST IMPOUNDMENT STUDY	235
7.0 LITERATURE CITED	237
8.0 PLATES	251
APPENDICES	267

LIST OF TABLES

<u>Table</u>		<u>Page</u>
S1	Summary of major potential impacts	xv
3.1	Total dissolved gas concentrations in the Columbia River below the Hugh Keenleyside Dam	22
3.2	Summary of total dissolved gas supersaturation bioassays compiled from literature sources	25
3.3	Summary of dissolved oxygen levels in the study area, 1976 to 1979	28
3.4	Mean heavy metal concentrations found in sediment samples from the Columbia River, 24 April 1980	30
3.5	Concentrations of mercury in the flesh of selected species of Columbia River fish subsequent to a spill at the Cominco Ltd. plant at Trail	31
3.6	Mysis relicta densities in the Columbia River below the Hugh Keenleyside Dam, 1980 and 1981	33
3.7	Fish species encountered in the Columbia River and tributaries, 1980 and 1981	35
3.8	Fish species composition in Lake Roosevelt, 1948 and 1962 to 1963	36
3.9	Numbers of fish captured or observed by various sampling methods and percentage composition of total catch in the mainstem Columbia River, 1980 and 1981	37
3.10	Night electrofishing catch and CUE for all sample sections in the mainstem Columbia River, 1980 and 1981	39
3.11	Day electrofishing catch and CUE for all sample sections in the mainstem Columbia River, 1980 and 1981	40
3.12	Gillnet catch and CUE for all sample sites in the mainstem Columbia River, spring to fall 1980 and winter 1981	41
3.13	Beach seine catch and CUE for sites in the mainstem Columbia River 1980 and 1981	42
3.14	Estimated numbers of kokanee in various electrofishing sections on the Columbia River, 11-18 July 1980	47
3.15	B.C. Fish and Wildlife Branch estimates of kokanee escapements in tributaries of the Columbia River, 1976 to 1980	50

<u>Table</u>	<u>Page</u>
3.16 Numbers of kokanee spawners enumerated in Norns Creek in 1980	53
3.17 Kokanee stomach content analysis, 1980	56
3.18 Comparison of age-length data for kokanee from the Columbia River and various locations within British Columbia	58
3.19 Electrofishing catch and CUE for all slow flowing sections of the mainstem Columbia River, 1980 and 1981	64
3.20 Electrofishing catch and CUE for all fast flowing sections of the mainstem Columbia River, 1980 and 1981	65
3.21 Rough estimates of the number of adult rainbow trout spawning in Norns Creek, spring 1981	68
3.22 Daily captures of rainbow trout at the trapping site in Norns Creek, spring 1981	71
3.23 Comparison of age-length data for rainbow trout from the Columbia River and its tributaries within the study area, and various locations within British Columbia	78
3.24 Comparison of age-length data for mountain whitefish from the Columbia River and various locations within British Columbia ..	87
3.25 Fecundity estimates for mountain whitefish from the Columbia River	88
3.26 Length and weight data for individual white sturgeon captured by anglers in the mainstem Columbia River and the Kootenay River, for 1973 and 1980	92
3.27 Twelve major angling areas between Trail and Hugh Keenleyside Dam	171
4.1 Preliminary estimates of the number of major sport fish which would be blocked by the Murphy Creek Dam	190
4.2 Estimated stream loss due to reservoir inundation and extent of accessible stream remaining in the major tributaries to the Murphy Creek Reservoir at the proposed normal reservoir operating level of el. 424 m, and at the two alternatives investigated	192
4.3 Estimated spawning habitat units lost due to reservoir inundation and spawning habitat units remaining in the accessible portion of the major tributaries to the Murphy Creek Reservoir at the normal reservoir operating level of el. 424 m, and at the two alternatives investigated	194

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.1	Murphy Creek Fisheries Study, 1980 and 1981, study area over-view map	3
2.1	Murphy Creek Fisheries Study, 1980 and 1981, study area sample locations	7
2.2	Murphy Creek Fisheries Study, 1980 and 1981, intensive sample area sample locations	8
3.1	Natural discharge of the Columbia River, 1914 to 1967	18
3.2	Monthly flows of the regulated Columbia River at Birchbank based on 1940 to 1975 computer simulation	19
3.3	Temperatures recorded in the Columbia River at Trail, 1969 to 1976	20
3.4	Total dissolved gas concentrations in the Columbia River below the Hugh Keenleyside Dam plotted against discharge, hydraulic head of the dam, and month	23
3.5	Generalized representation of cause and effect relationship in gas supersaturation-gas bubble disease-fish mortality	26
3.6	Seasonal variation in night electrofishing catches for major sport fish species in the Columbia River, 1980 and 1981	44
3.7	Kokanee and rainbow trout spawning utilization of Norns Creek	51
3.8	Scale sample from a kokanee captured on 8 May 1980 in the mainstem Columbia River	61
3.9	Scale sample from a kokanee captured on 2 September 1980 in Norns Creek	61
3.10	Relationship of water temperature and water level to daily number of rainbow trout entering the trap in Norns Creek, spring 1981	72
3.11	Gradient profile of Norns Creek	116
3.12	Gradient profiles of Columbia River tributaries	117
3.13	Norns Creek flow types	119
3.14	Norns Creek bank types	121

<u>Figure</u>	<u>Page</u>
3.15 Norns Creek substrate types	123
3.16 Gradient profile of Champion Creek	128
3.17 Champion Creek flow types	131
3.18 Champion Creek bank types	133
3.19 Champion Creek substrate types	135
3.20 Gradient profile of Blueberry Creek	139
3.21 Blueberry Creek flow types	141
3.22 Blueberry Creek bank types	143
3.23 Blueberry Creek substrate types	145
3.24 Gradient profile of China Creek	150
3.25 China Creek flow types	153
3.26 China Creek bank types	155
3.27 China Creek substrate types	157
3.28 Gradient profile of Murphy Creek	160
3.29 Murphy Creek flow types	161
3.30 Murphy Creek bank types	163
3.31 Murphy Creek substrate types	165
3.32 Habitat reaches and major angling areas	170
4.1 Area and storage capacity curves for the Murphy Creek reservoir	177
4.2 Simulated level of Murphy Creek reservoir operated under Regime 1 and Regime 2	178

LIST OF APPENDICES

<u>Appendix</u>	<u>Page</u>
A Summary of electrofishing catch, Columbia River Drainage, 1980 and 1981	267
B Summary of gillnet catch and CUE, Columbia River, 1980 and 1981	277
C Seine haul, fish trap, set line, and float survey summary, Columbia River, 1980 and 1981	283
D Summary of fish recaptures, Columbia River, 1980 and 1981	291
E Daily temperature and staff gauge recordings, April-May 1981	293
F Habitat Evaluation Procedure and results	297
G Area and storage capacity of the Murphy Creek Reservoir	303
H B.C. Fish and Wildlife Branch Report: Angler use and harvest of fish on the Columbia River, Keenleyside Dam - Trail 1980-81	305
I Terms of Reference	327

SUMMARY

INVENTORY OF AQUATIC RESOURCES

The remaining non-inundated reaches of the Columbia River in southeastern British Columbia support a variety of fish species, several of which contribute to a well-established sport fishery. Construction of the proposed Murphy Creek Project in the vicinity of Trail, B.C. would result in primary habitat alteration and is predicted to affect the diversity and abundance of sport fish populations. For this reason, R.L. & L. Environmental Services Ltd. was contracted to undertake an impact-related investigation of fish resources and habitat conditions.

The present study was largely confined to three main areas: (1) the mainstem Columbia River from the Hugh Keenleyside Dam (Km 57) downstream to Trail (Km 18), (2) the Kootenay River from the Brilliant Dam (Km 2.6) downstream to the Columbia River, and (3) numerous small tributaries entering these mainstem reaches (including Norns Creek, Champion Creek, Blueberry Creek, China Creek, and Murphy Creek). The investigation also included a limited amount of effort in the Columbia River between Trail (Km 18) and the International Boundary (Km 0).

Field investigations were conducted during each of the four seasons (i.e., spring 1980, summer 1980, fall 1980, winter 1981). Since spawning activity by the major sport fish species (i.e., rainbow trout and kokanee) occurs during spring and fall, sampling effort was greatest during these periods. An additional spring survey in 1981 (13 April to 8 May, 16 and 17 May) was undertaken to tag adult rainbow trout and to monitor rainbow trout spawning activities in tributary streams.

Field sampling on the mainstem Columbia and Kootenay rivers was conducted primarily from a 6.4-m jet drive riverboat; existing roads in the area provided access to tributary sampling sites. The primary capture gear employed included boat electrofisher, backpack electrofisher, fish traps, gill nets, beach seine, and set lines. In addition, underwater surveillance (i.e., field personnel equipped with wetsuit, mask, and snorkel) was conducted within the mainstem Columbia and Kootenay rivers.

Areas utilized for spawning by sport fish were located by several methods: direct capture of adults in spawning condition, collection of eggs, and observation of adults in potentially suitable habitat. Spawning escapements of kokanee into tributaries were enumerated by direct observation from stream banks. Aquatic habitat in the mainstem and tributaries was divided into discrete reaches and assessed on a site-specific basis according to the method developed by the B.C. Aquatic Studies Branch (1980).

During the study, 20 species of fish were collected in the Columbia River and its tributaries. A total of 110 729 fish were captured or observed in the mainstem Columbia River during five study intervals. Redside shiners dominated the catch (i.e., 78.4% of total); catostomids (suckers) also were abundant (i.e., 12.1% of total). Overall, coarse fish and minnow species accounted for over 90% of the catch. Ten species of fish with sport fishery value were captured in the area. Within this group mountain whitefish were the most numerous (i.e., 4.7% of total catch). Although kokanee and rainbow trout made a limited contribution to the total catch from the complete study area (i.e., 0.7% and 0.1%, respectively), they are the most highly valued of the sport fish species. Their status in the area was underestimated in the present study due to difficulty in sampling their preferred habitats.

During the summer, kokanee were well represented in the catch from the upper reach of the Columbia River (i.e., between the Hugh Keenleyside Dam and the Kootenay River confluence). This reach is evidently favoured due to its relatively low gradient (i.e., greater resemblance to preferred lentic environments). There are indications that two discrete populations of kokanee occur within the study area: (1) a migrant population of adults originating from Lake Roosevelt and (2) a population comprising smaller adults and juveniles entering from lower Arrow Lake (i.e., moving past Hugh Keenleyside Dam). Kokanee spawning has been recorded previously in Norns, Murphy, and China creeks (H. Andrusak, B.C. Fish and Wildlife Branch, pers. comm.). During the fall 1980, adult kokanee were observed by the present investigators in Norns Creek and Murphy Creek. Available data suggest that the Norns Creek escapement is a migrant stock originating from Lake Roosevelt. The extent to which kokanee utilize the mainstem Columbia River for spawning is unknown; however, it is apparent that some spawning

may occur upstream from Norns Creek. The upper reaches of the mainstem (i.e., above Castlegar) are used extensively for rearing by subadult age classes.

Although rainbow trout made a limited contribution to the total catch in this study (due to low sampling efficiency for this species in the mainstem Columbia River), they appear to be abundant in the study area and are the major focus of angling effort. Spawning migrations into Norns Creek and Champion Creek were documented. Evidence also suggests that rainbow trout spawn in the mainstem Columbia River. In the 1981 spring survey direct observations were made of rainbow trout spawning on a gravel and cobble shoal in the Kootenay River. Young-of-the-year rainbow trout were collected from Norns, Champion, Blueberry, China, and Murphy creeks, providing indirect evidence of their use for spawning. Resident populations of stunted rainbow trout occur in Champion, Blueberry, China, and Murphy creeks.

Dolly Varden are scarce in the study area; however, the presence of large individuals (possibly remnants of a pre-Hugh Keenleyside Dam riverine population) stimulates considerable sport fishing effort. Dolly Varden are most abundant in the upper mainstem reaches (i.e., near Hugh Keenleyside Dam). A reproducing population may exist in the study area although the presence of older juveniles and young adults could be due to fish moving out of the Arrow Lakes Reservoir or migrating upstream from Lake Roosevelt. No young-of-the-year Dolly Varden were captured in the study area. Suitable spawning habitat is restricted to the lower reaches of Norns Creek and possibly Champion Creek. Dolly Varden spawning in Norns Creek has been reported in previous years; however, no evidence of spawning was obtained in 1980 or 1981.

Mountain whitefish (all life stages) were common throughout the mainstem Columbia River. The large numbers of young-of-the-year observed in Norns Creek during the 1981 spring survey indicate that this stream is used for spawning. Furthermore, the large numbers of young-of-the-year in the mainstem indicate extensive spawning in the Columbia River. Although there is little information on the location of spawning in the mainstem, suitable habitat is widely available, particularly below Castlegar.

EFFECTS OF DEVELOPMENT

The Murphy Creek Project would involve the construction of a 28-m-high dam approximately 3 km upstream of Trail. The dam would create a reservoir (at its normal reservoir operating level of el. 424 m) approximately 34 km long that would extend upstream to the base of the Hugh Keenleyside Dam on the Columbia River, and to the base of the Brilliant Dam on the Kootenay River.

Initially, it is expected that the reservoir would be operated under Regime 1. This regime would result in an annual drawdown during the period January to June to facilitate evacuation of the Arrow Lakes Reservoir as required under the Columbia River Treaty.

To maximize electrical generation and to mitigate potential environmental impacts caused by reservoir drawdown, several alternative operating regimes for the Columbia River system have been investigated by B.C. Hydro. One of these, termed operating Regime 2, involves a reduction of the mean annual drawdown of the Arrow Lakes Reservoir and an increase in the mean annual minimum reservoir level. Under this regime, the Murphy Creek reservoir generally would be maintained at the normal operating level of el. 424 m throughout the year.

For most of the project life, Regime 2 is expected to be more representative of operation than Regime 1, and, therefore, has been chosen as the basis for project design. When the operating flexibility of the Columbia River Treaty improves following expiration of the Treaty (year 2024), it is expected that the operating regime may be further refined to increase power generation, improve flood control at Trail, or reduce the environmental impacts of reservoir drawdown.

Under either operating regime, daily reservoir water level fluctuations of up to 2.0 m would occur at the dam during the March to May period, with the daily fluctuations in the other months limited to 1.5 m. Daily fluctuations upstream of the dam would be slightly less depending on location and inflow. Daily fluctuations of the tailwater level at the dam would be limited to 3.0 m with hourly fluctuations of up to 1.0 m.

The potential impacts of the project on fish resources in the study are summarized in Table S1 for the three major project development phases (i.e., design/pre-construction, construction, operation). Impacts were evaluated as to their severity, duration, and geographical distribution; the potential for mitigation also was rated.

Impacts associated with design/pre-construction activities are expected to be of low severity, of short-term duration, and restricted in geographic scope. Construction impacts, although they may be of moderate to high severity, would be of short-term duration and restricted primarily to the immediate study area and downstream areas. The major construction-related impacts include hindrance or blockage of fish migrations, and increased sport fish harvest (i.e., due to fish concentration resulting from migration blockage, and localized population build-up).

Impacts resulting from the operational phase generally would be of high severity and long-term duration. The significance of impacts could extend beyond the immediate study area (i.e., regional, provincial, international) as a result of decreased sport fish populations outside the study area (i.e., downstream since some fish from as far downstream as Lake Roosevelt presently spawn upstream of the proposed damsite), as well as reduced local sport fishing opportunities for residents and tourists. The major adverse impacts would include blockage of fish migrations (e.g., kokanee, rainbow trout, walleye, etc.), loss of important/critical riverine habitat, and reduction of sport fish populations. The seasonal drawdown of the reservoir expected during the initial years of operation (Regime 1), and daily water level fluctuation, would severely limit overall fish productivity in the reservoir. Due to the limited amount of tributary habitat suitable for salmonid (i.e., rainbow trout, Dolly Varden, and kokanee) spawning within the study area, inundation of the lower sections of the tributaries would reduce sport fish recruitment in comparison to present conditions. The major positive or beneficial impacts of the development during this phase would include reduction of high total dissolved gas concentrations, and the initial development of a good tailwater sport fishery below the dam. The tailwater fishery, however, may be of short-term duration followed by a decline in catch per

Table S1. Summary of major potential impacts.

Phase	Negative Impact	Severity ^a	Duration ^b	Geogr. Distr. ^c	Potential ^d for Mitigation	Positive Impact	Extent ^a	Duration ^b	Geogr. Distr. ^c
Design/ Pre-Construction	Fish mortalities due to biological studies.	L	S	L	N	Increased awareness and participation in sport fishery.	L	L	L, R, P
	Decreased fish abundance due to increased angling pressure.	L	U	L	N				
	Effects on fish habitat.	L	S	L	H				
Construction	Hindrance or blockage of fish migrations.	H	S	L, I	M	Short term concentration of fish due to blockage, and subsequent increased sport fishery below dam.	M-H	S	L, R, P
	Decrease in water quality.	M	S	L, I	M				
	Reduction in stream flow.	M	S	L, I	U				
	Increased angling pressure.	M	M	L	H				
	Mortalities from explosives.	U	S	L	M-H				
	Ancillary facilities.	M	S	L	H				
Operation ^e	Blockage of migrations.	H	L	L, I	M	Overall increase in aquatic habitat.	M	L	L
	Loss of riverine habitat.	H	L	L	L	Increase in sport fishery downstream of the dam due to blockage, and loss of juveniles from reservoir.	M	U	L, R
	Loss of spawning habitat.	H-M	L	L, I	L-M				
	Loss of rearing habitat.	M	L	L, I	L-M				
	Decrease in benthic production.	M	L	L	L	Decrease in total dissolved gas concentration when reservoir is at full pool.	M-H	L	L, I
	Overall decrease in sport fish populations.	H	L	L, R, P, I	M				

^aSeverity/extent ratings: H = high, M = moderate, L = low, U = uncertain.

^bDuration: S = short term (less than 5 years), M = medium term (5-10 years), L = long term (greater than 10 years), U = unknown duration.

^cGeographical distribution—Distributional aspects (in terms of resource use) of impact: L = local, R = regional, P = provincial, I = international (i.e., U.S.A.). Regional and provincial distributional aspects relate primarily to loss or gain of the sport fishery as it would affect tourist angling opportunities. International distributional aspects relate to potential reductions in sport fish populations and reduction in water quality in the Columbia River and Lake Roosevelt in the U.S.A.

^dPotential for mitigation of adverse effects: H = high potential, M = moderate potential, L = low potential, U = unknown potential, N = not necessary due to low severity.

^eAssumes normal reservoir operating level at el. 424 m with reservoir operated under Regime 1.

unit effort due to the paucity of spawning habitat available in the immediate area.

Mitigation and enhancement opportunities exist to reduce some of the detrimental effects of the development. At the present time, the most suitable option available to enhance the sport fishery appears to be the development of a mini-hatchery to stock rainbow trout and kokanee in the reservoir. Seasonal drawdown and daily water level fluctuations, however, would decrease the effectiveness of any enhancement program.



1.0 INTRODUCTION

1.1 BACKGROUND

In an environmental overview of the proposed Murphy Creek development conducted by B.C. Hydro biologists in 1979, it was identified that the sport fishery along the Columbia River may well be the most important environmental resource component within the project area. During Stage II of the evaluation process, B.C. Hydro retained a team of consultants to conduct detailed environmental and socio-economic studies leading to an assessment of the impacts of hydroelectric development on the Columbia River in the vicinity of Murphy Creek. R.L. & L. Environmental Services Ltd. was responsible for undertaking the "fisheries and aquatic habitat" component of these studies.

This document presents and discusses the results of studies conducted in 1980 and 1981. An assessment of the probable impacts of the development and the potential mitigation options, based on available information, has been provided also. In addition to this volume, fisheries habitat information generated by the study has been included in the resource atlas prepared by Thurber Consultants Ltd.

1.2 STUDY AREA

The Columbia River originates from Columbia Lake in southeastern British Columbia. The river initially flows in a northerly direction between the Rocky Mountain and Columbia Mountain ranges. It then loops back and flows southward across the U.S.A.-Canada border before eventually draining into the Pacific Ocean at Portland, Oregon. At the Murphy Creek Project Site, the Columbia River has a drainage area of 155 000 km² (Water Survey of Canada 1980), which represents a large portion of southeastern British Columbia and northern Idaho and Montana.

The present study was confined largely to the mainstem Columbia River from the Hugh Keenleyside Dam (Km 57)^a downstream to Trail (Km 18), the Kootenay River from the Brilliant Dam downstream to the Columbia River, and the tributaries entering into the Columbia River within this area (Figure 1.1). Occasionally, fish sampling and tagging operations extended outside the principal study area to include the section of the Columbia River between Trail (Km 18) and the International Boundary (Km 0).

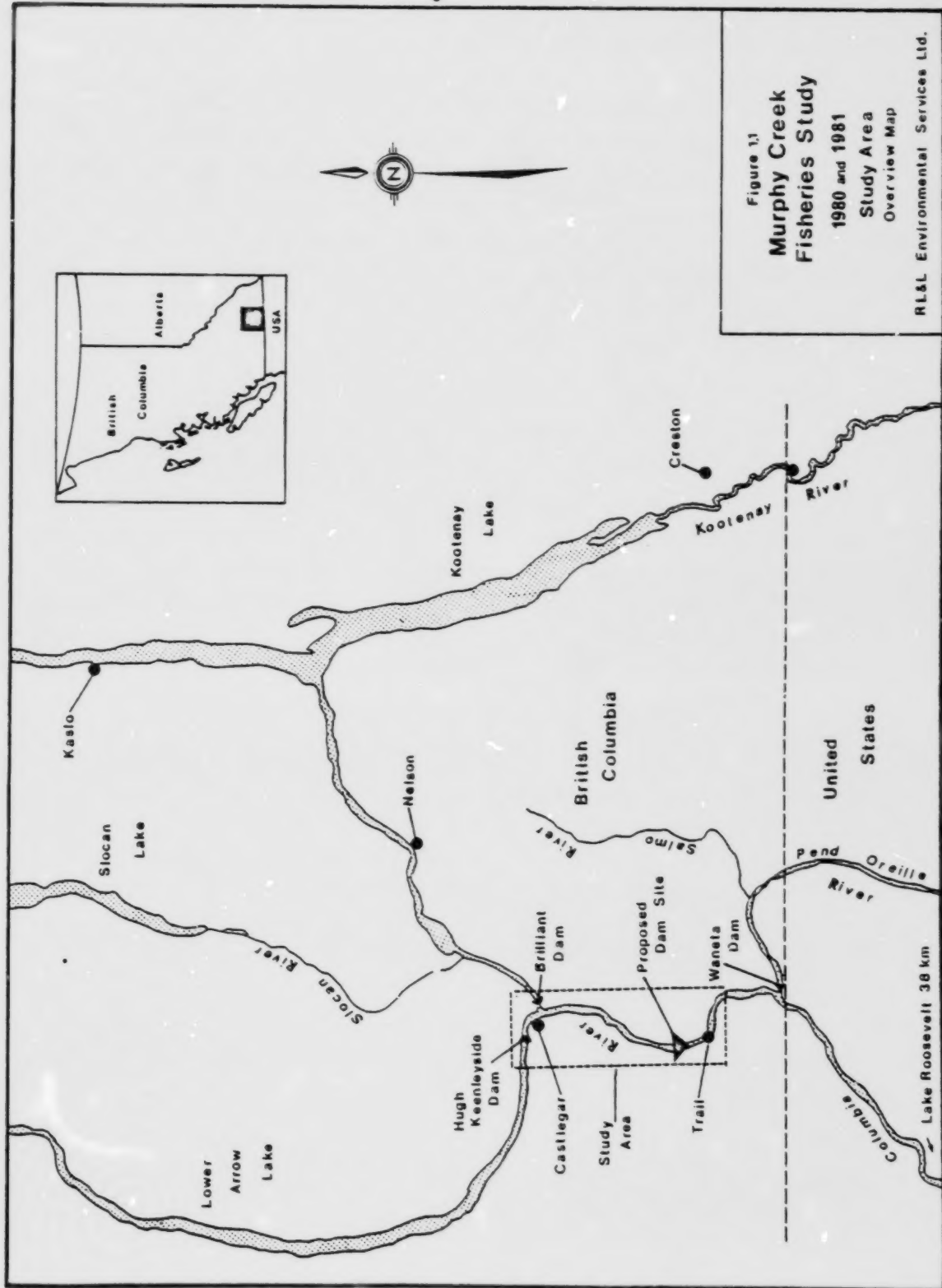
The Kootenay River, which enters the Columbia River at Km 45, is the largest tributary in the study area. Numerous smaller streams, including Norns (Pass) Creek, Champion Creek, Blueberry Creek, China Creek, and Murphy Creek, also enter the mainstem Columbia in the study area.

The Columbia River flows in a primarily straight, southerly direction through most of the study area. It is characteristically a single channel confined by the Monashee Mountains to the west and the Bonnington Range of the Selkirk Mountains to the east. This reach represents the only remaining free-flowing section of the Columbia River in the West Kootenays.

The Columbia River is navigable by recreational and commercial craft from Lake Roosevelt, U.S.A., upstream to Revelstoke, B.C. Access past the Hugh Keenleyside Dam is provided by navigation locks; these are available to both recreational and commercial traffic. Boat access up the Kootenay River is possible only to the Brilliant Dam, which is situated 2.6 km upstream from the confluence of the Kootenay and Columbia rivers.

The mean annual discharge of the Columbia River measured directly upstream of the Kootenay River confluence, from 1961 to 1980, was $1169 \text{ m}^3/\text{s}$ (Station No. 08NE002, Water Survey of Canada 1980); discharge has been regulated since the completion of the Hugh Keenleyside Dam in 1968. The mean annual discharge downstream of the Kootenay River confluence, measured over the period 1937 to 1979, was $2020 \text{ m}^3/\text{s}$ (Station

^aIn this report, distances along the mainstem Columbia River are given in kilometres upstream of the Canada-U.S.A. border.



No. 08NE049; Water Survey of Canada 1980). Discharge does not change appreciably between the Kootenay River-Columbia River confluence and the Pend Oreille River-Columbia River confluence immediately north of the International Boundary.

1.3 STUDY OBJECTIVES

The principal objectives of this study were two-fold. The first was to provide an inventory of fish resources and aquatic habitat in the mainstem Columbia River and those tributary reaches which would be influenced by the proposed development. Emphasis was to be placed on determining species composition and relative abundance, identifying fish movement patterns, and identifying and mapping important fish habitat. Secondly, the potential effects of the proposed development on the aquatic resources, and feasible mitigation opportunities, were to be identified and evaluated.

2.0 METHODOLOGY

2.1 STUDY SCHEDULING

Field investigations were conducted seasonally, with the survey periods as follows:

- (1) Spring 1980 (29 April-11 May)
- (2) Summer 1980 (11-18 July)
- (3) Fall 1980 (26 August-11 September)
- (4) Winter 1980 (29 January-6 February)
- (5) Spring 1981 (13 April-8 May; 16-17 May)

Sampling effort was greatest in the spring and fall, since the majority of spawning activity by sport fish occurs during these periods. Office analyses of the field data were conducted between field periods and during the summer of 1981.

2.2 SOURCES OF BACKGROUND INFORMATION

Background information was obtained from a variety of sources. The B.C. Fish and Wildlife Branch and the Washington Department of Game provided data on the life histories and population parameters of fish species in the Columbia River drainage. Local resource users (i.e., the Castlegar and Region Wildlife Association, Trail Wildlife Association, and individual anglers) provided information on fish distribution and catch rates in recent years.

2.3 LOGISTICS

Field investigations on the mainstem Columbia and Kootenay rivers were conducted from a 6.4-m jet drive riverboat. Suitable boat launching sites on the Columbia River were available at Robson and at Trail. Access to the smaller tributaries was obtained via Highway #3 and 3A. A three-man crew was employed during most of the study periods.

2.4 SAMPLING SECTIONS

Sampling locations for the major sample methods employed during the study are illustrated in Figure 2.1. Within this general area an intensive sample section was established from the Castlegar Ferry crossing to the Hugh Keenleyside Dam. Sample locations within this area are presented in Figure 2.2.

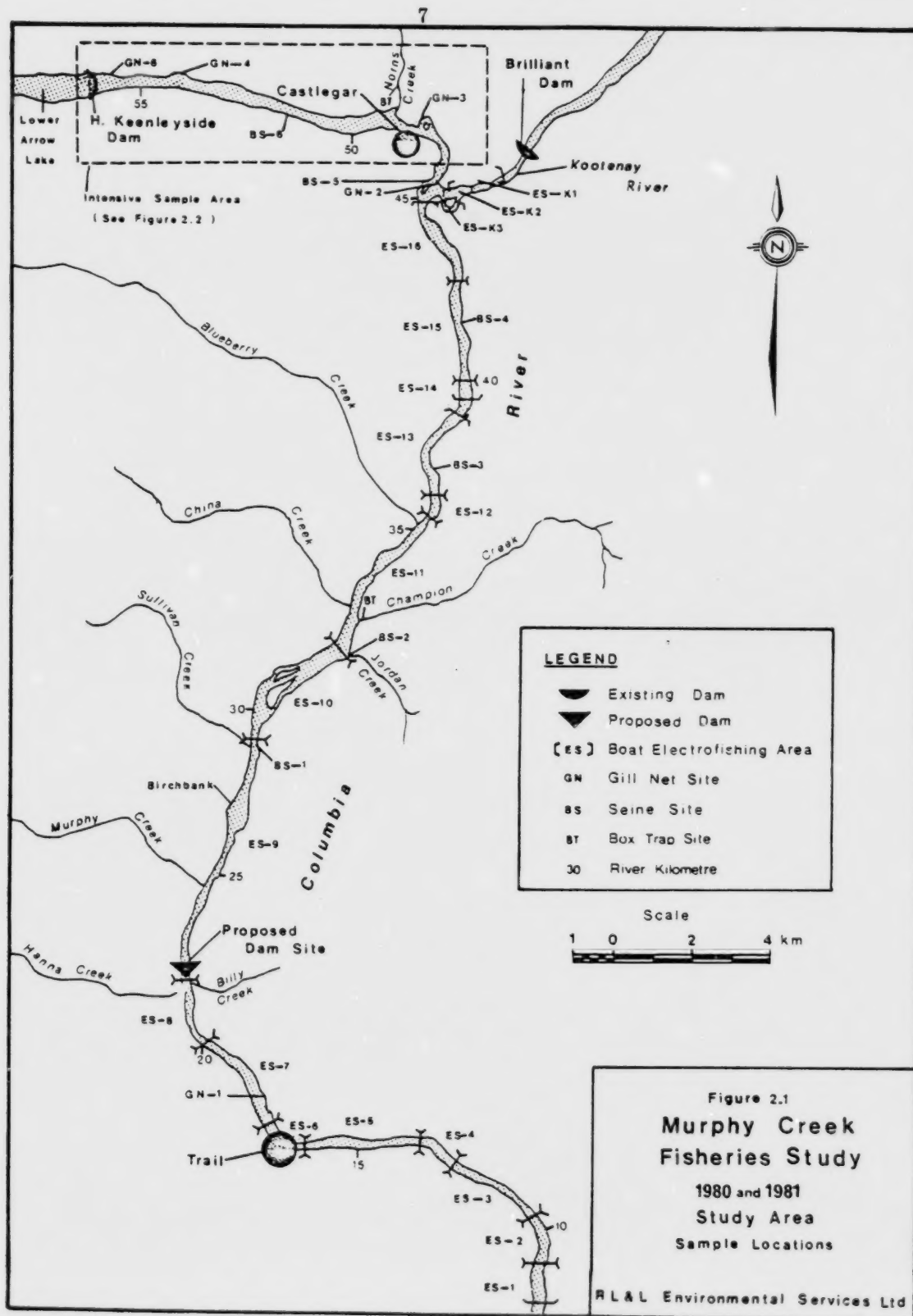
2.5 FISH COLLECTION TECHNIQUES

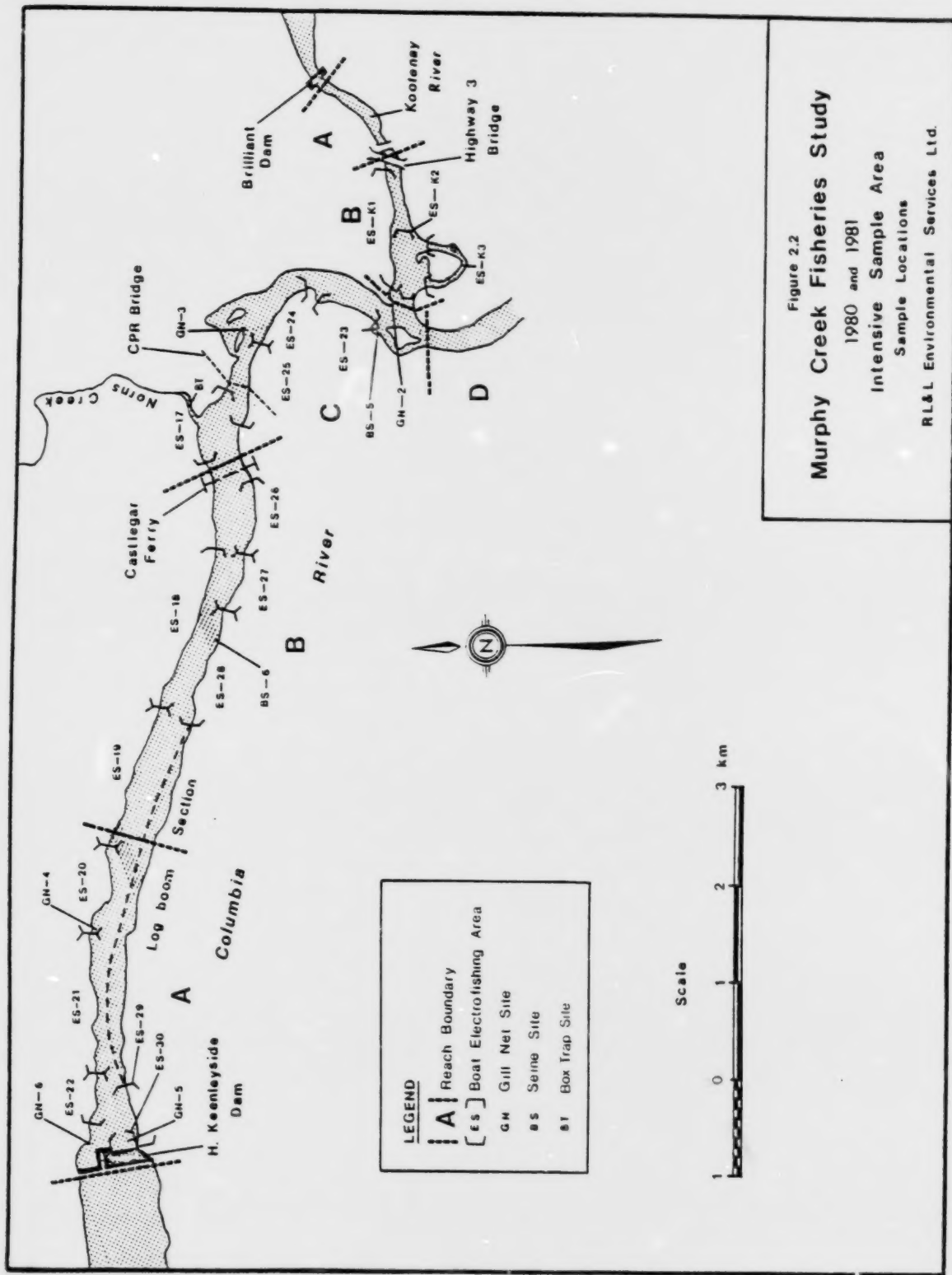
2.5.1 BOAT ELECTROFISHING

The primary objectives of the electrofishing program were to monitor seasonal changes in species composition and relative abundance of fish populations in the study area, and to obtain specimens in good physical condition for tagging. Initially, the tagging studies were implemented in an attempt to estimate population size for the major sport fish species; however, it soon became apparent that sampling difficulties would prevent the capture and tagging of sufficient numbers of fish to provide population estimates using mark-recapture methods.

The sampling gear consisted of a boat-mounted Smith-Root Type VI electrofisher, which converted 220 VAC from a 4500-W generator into pulsed DC. Electrical current was directed into the water through a hand-held anode which consisted of a 25.4-cm-diameter metal ring covered with 0.64-cm mesh nylon seine material and attached to a 2.0-m insulated anode pole. The cathode lead was connected directly to the transom of the aluminum riverboat. Pulse configuration consisted of a triangular wave (fast rise, slow decay) at 60 Hz. The majority of shocking was conducted with the unit producing 500 to 825 VDC at 2.0 to 4.0 A. These parameters have been shown to be effective in attracting fish within netting distance while causing minimal physiological damage to the fish (Taylor et al. 1957; Vincent 1971).

The boat electrofishing procedure consisted of drifting downstream through defined sampling sections. The boat was maintained near shore, with the anode positioned between the boat and shoreline. Work assignments among the three-man crews were standardized to promote optimum crew





efficiency. The mesh size of the capture net resulted in a negative bias for small fish (i.e., less than 15 cm in length). Fish escaping the electric field or avoiding the netter were enumerated by crew members and recorded as "observed" at the end of the sample section. The same was true for juvenile fish or cyprinids that were not collected. Captured fish were transferred immediately to on-board live tanks and were processed upon completion of a sample section or when the holding capacity of the tanks was reached. Fresh water was added periodically to replenish the oxygen supply and reduce stress. Habitat types and preferences of the various species were observed and noted. Water temperature was recorded with a pocket thermometer to the nearest 0.5 °C. Electrofisher settings, amperage produced, and sampling effort (seconds and kilometres shocked) also were recorded along with estimated sampling efficiency, and factors limiting sampling efficiency.

Electrofishing was conducted during both day and night periods. Night electrofishing was by far the most successful method of catching fish, and therefore was utilized most often. The majority of night electrofishing was conducted in the Columbia River mainstem within the intensive sample area near Castlegar. In downstream reaches (i.e., from Castlegar to Trail) the higher gradient and abundance of rapid sections prevented night electrofishing for reasons of crew safety.

A total of 30 electrofishing sections were established on the mainstem Columbia River (Figures 2.1 and 2.2). Sections located in the intensive sample area generally were sampled at least once during each of the four survey periods; the remaining sections were electrofished on an irregular basis.

2.5.2 BACKPACK ELECTROFISHING

The major objective of the backpack electrofishing program was to determine seasonal species composition and relative abundance of fish in small tributaries (i.e., those which will be affected by the proposed development). Secondly, it provided an indication of the use of these areas by the various species and life stages, and provided specimens for life history analysis.

Electrofishing was conducted using a Smith-Root Type VII backpack electrofisher. This method is ideally suited for sampling small streams and tends to be one of the least selective of all sampling techniques (Libosvarsby and Lelek 1965, cited in Dietz 1971). Electrofishing was conducted in at least two representative reaches of selected tributaries during each of the seasonal surveys. Study reaches were 50 to 100 m in length and were sampled in an upstream direction. An attempt was made to sample the entire stream channel. Although stream widths or depths did not permit total channel coverage in all reaches, each of the discrete habitat types was sampled.

The sampling efficiency of backpack electrofishing was generally rated as high. The unit produced 0.5 to 2.0 A at voltage settings of 400 to 600 VDC. Sampling efficiency was reduced in streams where conductivity was low or depths exceeded 1.0 m (e.g., Norns Creek). For the most part, average stream depths were substantially less than 1.0 m and were not a factor limiting capture success. Fish escaping the electric field or avoiding the netter were enumerated and recorded as "observed" at the end of the sample section. Captured fish were handled in a manner similar to that described previously for the boat electrofishing method.

2.5.3 GILLNETTING

A gillnetting program was instituted to supplement electrofishing data on species composition and relative abundance, identify movement trends and chronology, provide specimens for life history analysis, and sample specific habitats not susceptible to other gear (e.g., deep pools). Monofilament gill nets of various mesh sizes (3.8-cm, 6.4-cm, and 10.2-cm stretched measure) and consisting of 2.4-m by 15-m panels were employed during this study.

Six gill net sites were established within the study area (Figure 2.1). Nets were used on an irregular basis, with set duration strongly influenced by fluctuations in water level. Water temperature, visibility, net efficiency, and the catch for each mesh size were recorded.

Due to extensive amounts of debris in the water (i.e., logs, detached filamentous algae, vegetation, fibrous material), the efficiency of gill nets

was generally low throughout the study. Submerged sets exhibited higher overall capture rates than surface sets; however, due to debris problems on the bottom (e.g., logs) and boulder substrate, bottom net sets were used sparingly.

2.5.4 FISH TRAPPING

2.5.4.1 Hoop Traps

In an attempt to obtain data on the timing and extent of fish movements past the proposed damsite during the spring of 1980, a hoop trap was utilized. The 3-m-long hoop trap was constructed of 87-cm-diameter conduit frames covered with 3.8-cm mesh Vexar^a plastic netting. The trap was set along the shore in the Columbia River near the proposed damsite. Leads constructed of Vexar were used to direct fish into the trap.

The extreme water level fluctuations in the Columbia River (up to 2 m) and excessive debris, greatly reduced capture efficiency. As a result, use of this method was discontinued after a short trial period.

2.5.4.2 Minnow Traps

Gee minnow traps were used in an attempt to provide additional data on the use of the Columbia River mainstem by young-of-the-year and juvenile fish, and by other small fish (e.g., cyprinids). The baited traps were placed in shallow backwaters or nearshore areas and were checked on alternate days. Due to the low catch of fish by these traps (partly due to fluctuating water levels), their use was discontinued after a short trial period.

2.5.4.3 Box Traps

Upstream- and downstream-oriented fish traps (box traps) were utilized in the lower sections of Norns Creek and Champion Creek during the period 14 April to 8 May 1981. The purpose of the fish trapping program was two-

^aDu Pont of Canada trademark.

fold. Firstly, it would provide adult rainbow trout for tagging to develop additional data on the timing and extent of rainbow trout movements in the Columbia River study area. Secondly, it would give an indication of the utilization in two major spawning locales.

The traps were constructed of wood and measured 1.3 m x 1.3 m x 1.3 m. Funnel entrances measured 30 cm x 30 cm reducing to 30 cm x 8 cm. The traps were set in the main channels of the tributaries in locations characterized by moderate current velocities, and depths between 0.4 and 0.8 m. Wings constructed of Vexar plastic netting were angled into the current to direct fish into the trap.

The traps were checked and cleaned daily. Water and air temperatures, water visibility, trap efficiency, and water depth at the trap entrance were recorded at each inspection. The traps operated continuously after installation until washed out by high water levels; heavy rains and resultant high water levels rendered the Norns Creek fish trap ineffective during the periods 23 to 24 April and 30 April to 4 May. In Champion Creek, high water levels coupled with severe debris problems required removal of the trap during the period 24 to 27 April.

2.5.5 BEACH SEINING

Use of the mainstem Columbia River for rearing by young-of-the-year and juvenile sport fish and by other small fish (i.e., cyprinids) was determined by a repetitive seining program. A beach seine, 9.1 m in length and 1.5 m in depth with 1.27-cm nylon mesh (collection bag of 0.64-cm mesh), was utilized. The length, width, maximum depth, median depth, and efficiency of each haul were recorded for each site. Captured fish were identified and enumerated, and fork lengths of a representative sample were recorded. Water temperature and habitat conditions also were recorded.

Seine haul sites, designated for repetitive sampling, were established at six locations on the Columbia River (Figure 2.1). Sampling at these sites was conducted once during each of the initial four survey periods (i.e., spring 1980 to winter 1981). Additional sampling on the mainstem was conducted on an

opportunistic basis during the summer survey to determine more precisely the extent of use of the river by salmonids for rearing.

2.5.6 SET LINES

The use of set lines was directed primarily at burbot since this species is not particularly vulnerable to other sampling methods. Set lines consisted of a baited No. 0 treble hook attached to a 23-kg test monofilament line. Set lines were placed in deep pools or backwaters in the upper section of the study area (i.e., above Castlegar) and were checked daily.

2.5.7 FLOAT SURVEYS

Selected areas within the Kootenay and Columbia rivers (i.e., those too deep for efficient sampling by electrofishing and exhibiting a high water clarity) were visually observed during longitudinal swim transects. Using a mask and snorkel, a swimmer floated downstream through river sections and visually identified and enumerated the fish present. Total observation time, length of channel surveyed, visibility, physical parameters, and fish observed were recorded upon completion of the transect. Due to the depth of the main channel throughout much of the Kootenay and Columbia rivers, this method was useful only near shore or over shallow (i.e., less than 4 m) areas of the mainstem.

2.6 LOCATION OF SPAWNING AREAS

Areas utilized by sport fish species for spawning were located by a variety of methods. The collection of both ripe and spent individuals was considered to be an indication of actual spawning in an area. Direct observations of fish in the tributary streams or collection of eggs in or on the substrate also were used to identify spawning areas. The latter technique involved physically disturbing the substrate (approximately 0.5 m^2) and collecting drifting eggs in a dip net (1 mm mesh) positioned downstream of the sampled area.

2.6.1 ESCAPEMENT ESTIMATES

Estimates of kokanee escapement into the Columbia River tributaries were based on visual enumerations. Two observers simultaneously walked the stream banks and enumerated the kokanee which were generally readily visible in the clear, shallow waters. These counts were then averaged and a range obtained. Counts were conducted on selected tributaries at least twice during the spawning period. Since field sampling during the fall of 1980 was conducted only during the period 26 August to 11 September, it is possible that an earlier or later run of kokanee into spawning streams could have been missed; however, the absence of carcasses at the beginning of the field sampling appeared to indicate that earlier spawning runs had not occurred, and conversations with local residents indicated that later runs (i.e., after the completion of the field studies) did not occur.

2.7 MYSID SAMPLING

To provide information on the density and distribution of *Mysis relicta* in the section of the Columbia River upstream of the ferry crossing, a limited sampling program using tow nets was implemented. Two sizes of net were utilized—one with a mouth diameter of 39 cm and the other with a mouth opening of 41.5 cm x 37.5 cm. Each of the nets was 2.1 m in length and constructed of 1-mm mesh material tapered to a collection bucket. Three total vertical tows were composited at each sample location. Densities were expressed in numbers per square meter of surface area.

2.8 FISH MARKING

Fish captured during the study were tagged to provide information on fish movements within the study area. Fish in good physical condition at the time of capture and exceeding 200 mm in length were marked with labelled Floy FD67 anchor tags.^a The tag was inserted into the dorsal musculature immediately below the insertion of the dorsal fin and between the second and third dorsal fin rays. Tagged fish were released near their point of capture. In an attempt to determine the mobility of smaller fish within the study sections, fin-clipping was conducted. For salmonid species this involved the

removal of the adipose fin and/or pelvic fin. Other species were marked by the removal of one pelvic fin.

2.9 FISH LIFE HISTORY DATA

2.9.1 COLLECTION PHASE

Pertinent life history data were collected from all fish species captured in the study area; however, emphasis was placed on sport fish species. Fork length to the nearest millimetre was recorded and weight determined on either a Chatillon Model 1038B spring scale (0 to 5000 g) or a Hanson Dietary scale (0 to 500 g). Sex and maturity were determined by dissection, external examination, or, during spawning seasons, release of sexual products. Scales were collected from the area immediately below the anterior insertion of the dorsal fin on the left side of the fish. They were then placed in envelopes for later processing. Otoliths were dissected from selected individuals and stored dry. Stomach contents were either examined cursorily in the field or the entire stomach was removed and stored in a 10% formalin solution for later analysis. All life history data were entered on fish data sheets for subsequent computer tabulation and analysis.

2.9.2 ANALYSIS PHASE

Fish aging was accomplished by mounting fish scales between glass microscope slides and then viewing with a 3M Model SRC816 microfiche reader or a binocular dissecting microscope. Otoliths were cleared in 2% KOH and aged using a binocular dissecting microscope.

In this study, kokanee were assigned ages according to the "freshwater method" (i.e., age corresponds to the number of annuli) as opposed to the Gilbert system (i.e., the year of life and the number of years in freshwater are indicated). For example, a 2+ kokanee according to the freshwater method (two annuli and in its third year of life) corresponds to an age 3₃ fish in the Gilbert system. In order to avoid confusion resulting from seasonal sampling, fish ages were adjusted to correspond to the calendar year (e.g., a fish caught in the spring prior to annulus formation was aged as the number of annuli plus one). Kokanee scales which exhibited obvious resorption were

not used in life history analyses. Ages were entered on the data sheets, and the information was then transferred to computer cards. Sorting and analyses were performed on the B.C. Hydro computer in Vancouver.

Preserved stomachs were evacuated after determination of fullness (after Thompson 1959). The organisms present were then identified to order and percentage composition calculated.

2.10 HABITAT SURVEYS

Aquatic habitat in the Columbia River within the study area was initially pre-typed into discrete reaches (i.e., displaying relatively homogeneous habitat conditions) by analyses of airphoto mosaics and gradient profiles. Subsequent observations in the field provided validation of the initial pre-typing.

The aquatic habitat of tributary streams was surveyed by foot. General habitat characteristics were noted throughout the surveyed reach. Detailed measurement of selected physical stream characteristics was conducted at 60-m intervals. Habitat evaluation procedures were similar to those described by the B.C. Aquatic Studies Branch (1980). Particular attention was directed to the identification of important and critical habitat (i.e., potential spawning and rearing areas), particularly those which would be altered or affected by increased water levels.

Photographic plates illustrating habitat conditions of the various streams surveyed are presented at the end of this report.

3.0 INVENTORY OF AQUATIC RESOURCES

3.1 GENERAL LIMNOLOGY

3.1.1 WATER QUALITY

3.1.1.1 Physical

(a) Discharge

The monthly flows of the Columbia River at Birchbank (Km 27) prior to regulation of the river are presented in Figure 3.1. Monthly flows of the regulated river, based on a 1940-1975 computer simulation, are shown in Figure 3.2. Since the construction of the Hugh Keenleyside Dam in 1968, the seasonal variation in flow has decreased. As is typical of regulated rivers, summer peaks have been reduced relative to natural flows while winter lows have been increased. Peak discharge occurs in winter (about $3400 \text{ m}^3/\text{s}$) and subsequently declines to a low in March-April (about $1400 \text{ m}^3/\text{s}$). Discharge increases through spring and is relatively stable from May to August (about 2100 to $2800 \text{ m}^3/\text{s}$). Flows decrease and reach a low in the fall (about $1400 \text{ m}^3/\text{s}$); subsequently they increase during winter.

(b) Temperatures

Minimum and maximum water temperatures at Trail from 1969-1976 are shown in Figure 3.3. Water temperatures are lowest during January-February (about 0.5° to 4°C) and gradually rise to a peak in July-August (about 13° to 19.5°C).

(c) Dissolved Gas Saturations

The Columbia River below the Hugh Keenleyside Dam has been identified as having the highest total dissolved gas (TDG) concentrations of the 35 major rivers or lakes examined in British Columbia (Clark 1977). A total dissolved gas concentration of 144% saturation was recorded by the B.C. Pollution Control Branch on 17 August 1976.

High concentrations of dissolved gases can be maintained for a substantial distance downstream. High levels at the Grand Coulee Dam and

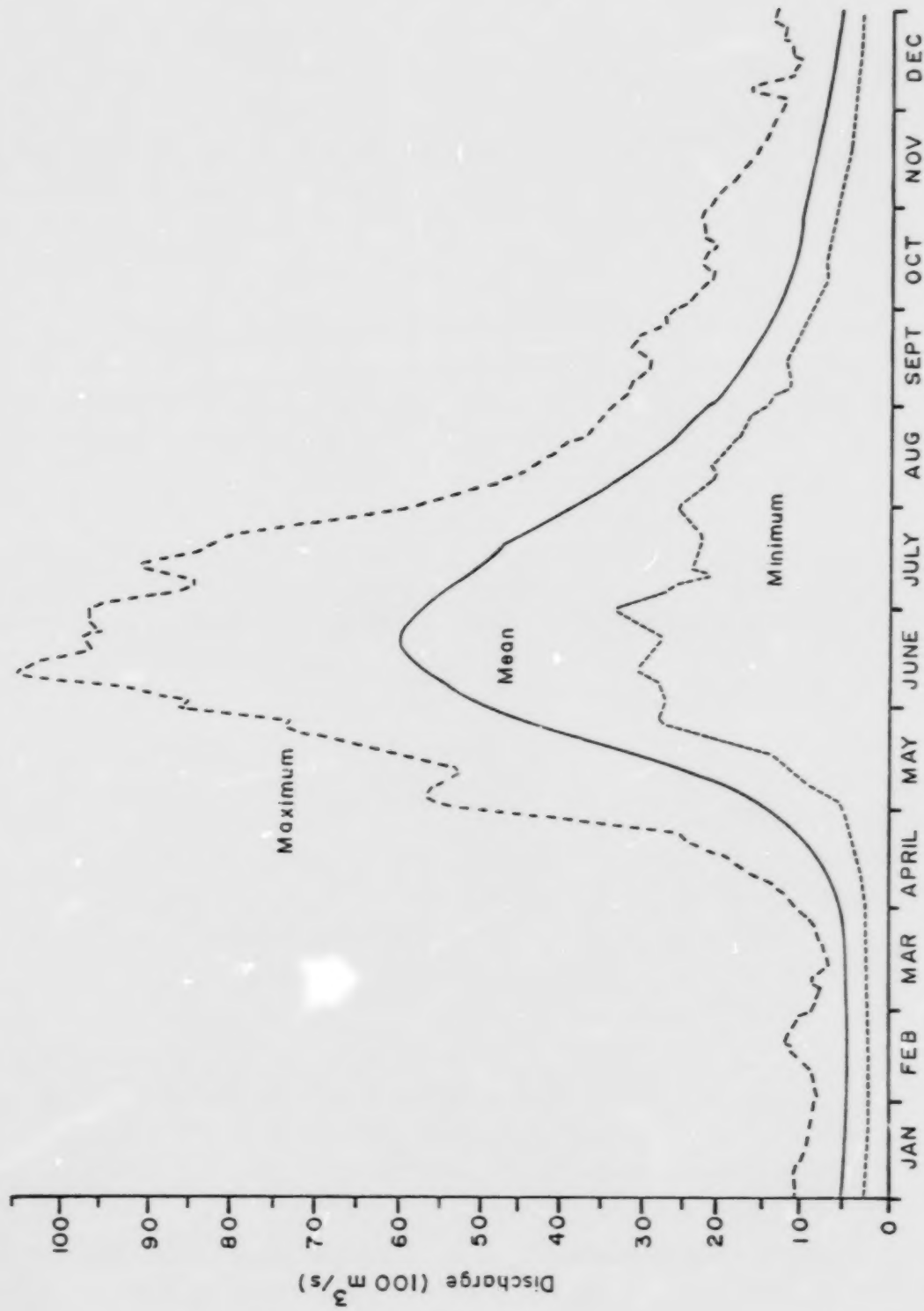


Figure 3.1. Natural discharge (pre-regulation) of the Columbia River, 1914 to 1967. (Source: B.C. Hydro 1981a.)

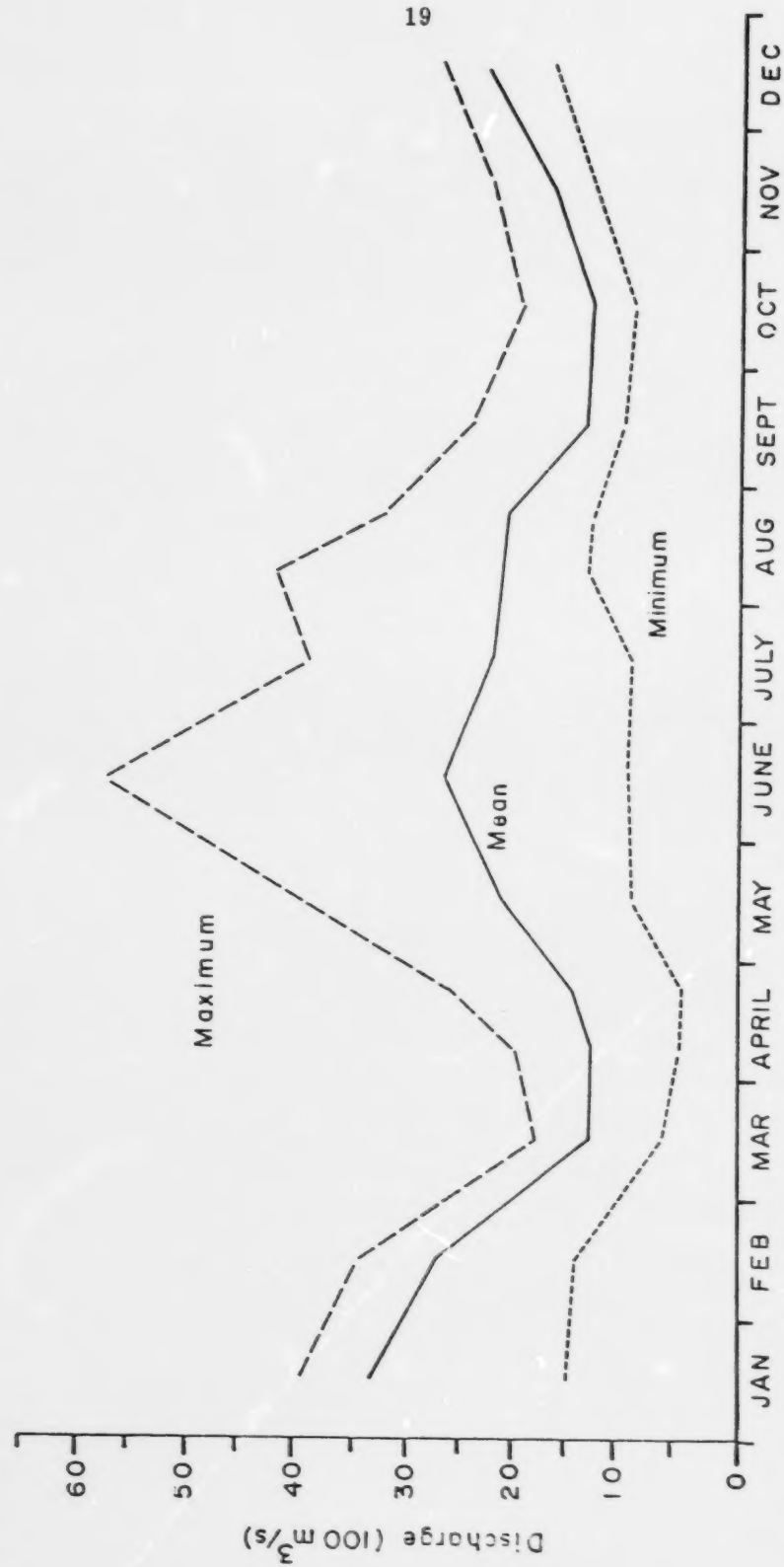


Figure 3.2. Monthly flows of the regulated Columbia River at Birchbank based on 1940 to 1975 computer simulation of regulated conditions. (Source: B.C. Hydro 1981a)

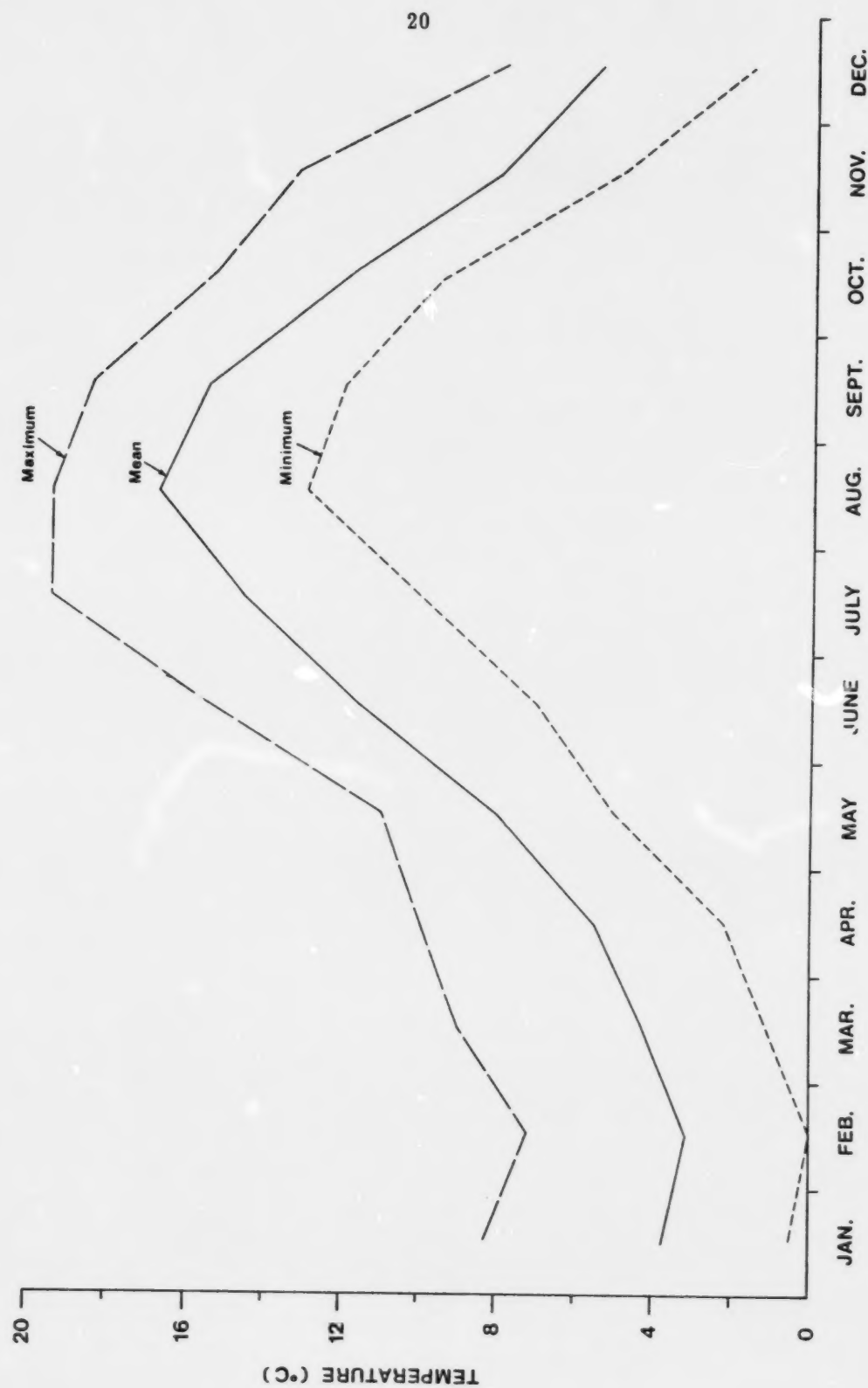


Figure 3.3. Temperatures recorded in the Columbia River at Trail, 1969 to 1976. (Source: B.C. Hydro 1981a)

throughout Lake Roosevelt in Washington have been attributed to supersaturation occurring at upstream dams on the Columbia River in Canada (Seattle Marine Laboratories 1972). The total dissolved nitrogen levels in water entering Lake Roosevelt (above 120% saturation from April through August) decreased only slightly (2% or 3% saturation) as the water moved the 225 km through the lake to the Grand Coulee Dam (Seattle Marine Laboratories 1974).

In an attempt to determine the major factors affecting the concentrations of dissolved gases in the river water, saturation levels reported by Clark (1977) were plotted against discharge, hydraulic head^a at the Hugh Keenleyside Dam, and month (Table 3.1; Figure 3.4). No clear relationships were shown although a slight positive correlation was noted between TDG saturation and hydraulic head ($r^2 = 0.38$). It was evident that high TDG saturation levels tended to occur when the spillway, as opposed to the low level ports, was used to discharge water. Statistical analyses (Student's t-test) showed that the mean TDG levels during periods when only the spillway was discharging ($\bar{x} = 128.9\%$; $n = 22$) were significantly higher ($p < 0.01$) than the mean concentration during periods when only the low level ports were discharging ($\bar{x} = 102.6\%$; $n = 7$).

Total dissolved gas concentrations that likely would have occurred in the Columbia River during the present study were estimated based on TDG concentrations reported previously, river discharge at the time, and mode of operation (i.e., spillway versus low level port discharge). These estimates are as follows:

^aHugh Keenleyside Dam operating information (i.e., discharge, head, number of spillway gates or ports operating, etc.) supplied by H.A. Smith, B.C. Hydro (from memo dated 17 March 1981 from W.N. Tivy to H.A. Smith).

Table 3.1. Total dissolved gas (TDG) concentrations in the Columbia River below the Hugh Keenleyside Dam.

Date	TDG ^a % Sat.	Discharge ^b (m ³ /s)	Hydraulic Head (m) ^b	No. of Ports Open ^b	No. of Spillway Gates Open ^b
Discharge Through Ports Only					
25 Jan. 1973	99.3	1418	6.21	3	
1 Mar. 1973	100.0	213	5.36	3	
28 Mar. 1973	100.8	142	6.25	2	
4 May 1973	104.4	273	6.25	4	
13 June 1973	105.7	555	7.40	3	
22 Aug. 1973	104.3	1994	1.66	8	
18 Mar. 1976	104.0	915	9.16	3	
Discharge Through Ports and Over Spillway					
6 Jan. 1973	111.8	1920	8.85	2	4
16 Mar. 1976	103.7	885	9.19	1	4
17 Mar. 1976	121.0	967	8.96	3	4
Discharge Over Spillway Only					
11 June 1972	132.0	2694	10.91		4
22 June 1972	135.8	4357	11.81		4
22 June 1972	135.1	4357	11.81		4
25 July 1972	131.6	3005	17.67		4
25 July 1972	133.8	3005	17.67		4
21 Aug. 1972	128.7	1752	19.94		4
13 Sept. 1972	115.4	668	22.32		4
17 June 1974	113.2	146	13.16		1
18 June 1974	110.3	148	13.62		1
3 July 1974	100.6	1427	17.40		4
24 Oct. 1974	115.8	861	16.36		4
13 June 1975	129.7	148	11.74		1
15 June 1975	132.8	145	12.60		1
16 June 1975	132.8	146	13.07		1
25 July 1975	134.1	147	15.94		1
17 June 1976	131.0	857	14.05		4
8 July 1976	138.4	864	19.05		4
22 July 1976	133.1	2287	18.48		4
7 Aug. 1976	121.8	3177	17.86		4
17 Aug. 1976	144.0	3757	16.87		4
19 Aug. 1976	143.0	3587	17.55		4
20 Aug. 1976	142.5	3041	17.80		4

^a from Clark (1977).

^b from B.C. Hydro (unpubl. data).

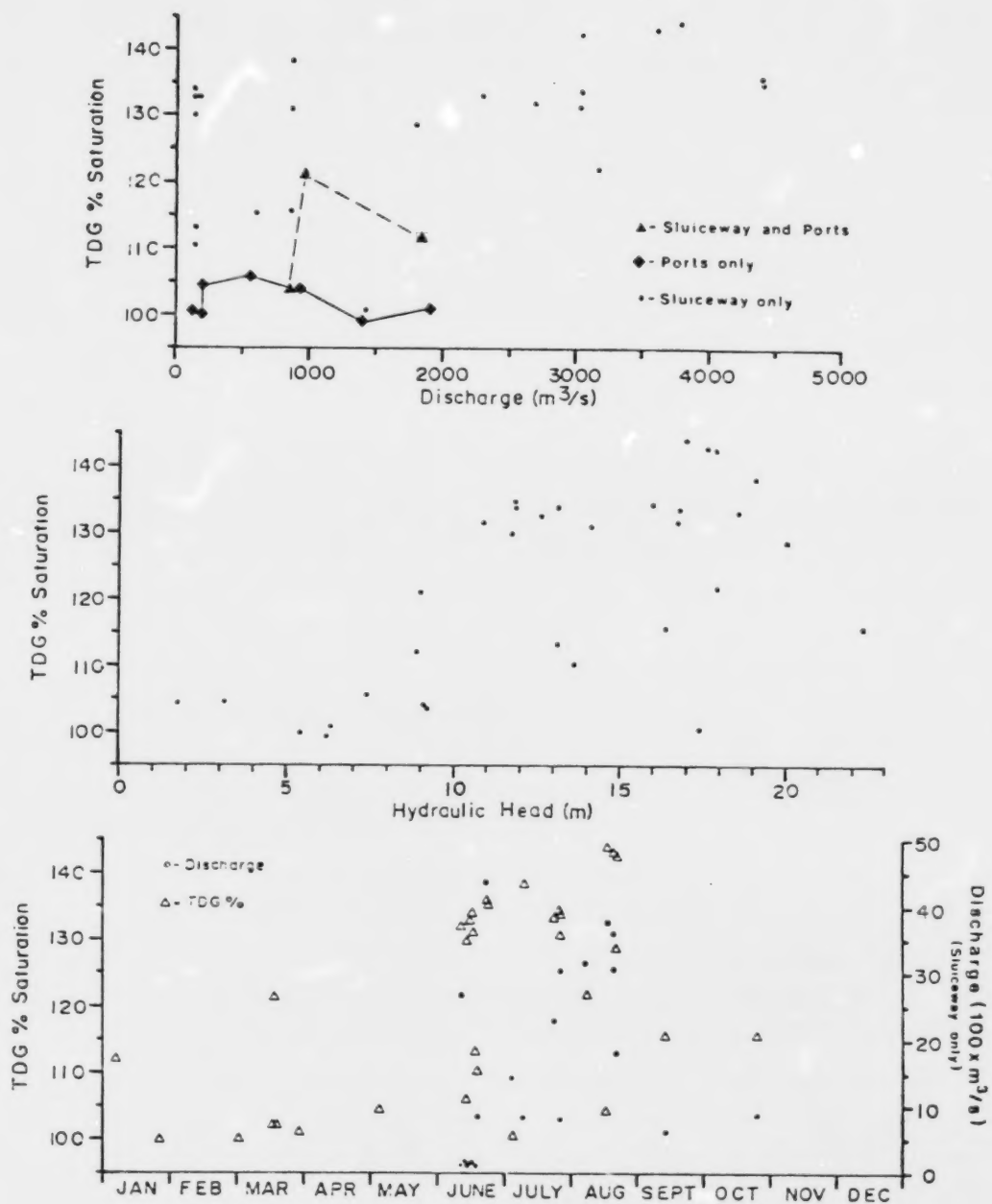


Figure 3.4. Total dissolved gas concentrations (TDG) in the Columbia River below the Hugh Keenleyside Dam (1972 to 1976) plotted against discharge, hydraulic head of the dam, and month (from Clark 1977; B.C. Hydro, unpubl. data)

<u>Period</u>	<u>Discharge</u> <u>(m³/s)</u>	<u>Mode of</u> <u>Discharge</u>	<u>Probable Range of</u> <u>TDG Concentration</u>
2-3 May 1980	715-722	Ports	100-105%
5 May 1980	200	Spillway	110-135%
11-14 July 1980	1077-1193	Spillway	115-135%
26-29 Aug. 1980	1270-1361	Spillway	120-135%
28-31 Jan. 1981	1867-1885	Spillway	125-135%

According to the literature, a wide range of TDG saturation can cause high mortality in test animals (Table 3.2). Some investigators report coarse fish species (e.g., northern squawfish) as being more resistant than salmonids when stressed with supersaturation (Blahm 1974, cited in Bentley et al. 1976), while other researchers have indicated coarse fish to be of equal or lower tolerance (Meekin and Turner 1974). Variation within a species also may be high. For example, Fickeisen and Montgomery (1978) recorded time to lethal exposure for 50% mortality (LE50) for cutthroat trout held at 128% TDG saturation as 12 hours, while May (1973) reported the LE50 for this species at 125% to 131% TDG, as being 53 hours. Depth of testing, among other variables, can result in LE50 variation. Ebel et al. (1975) reported that when confined to a depth less than 0.5 m, juvenile steelhead trout had significant mortality (i.e., 50%) at 115% saturation after 20 days. Also, if the saturation level exceeds 120%, substantial mortality (i.e., 50%) would occur after 20 days' exposure even if the fish were allowed to sound to greater depths (i.e., tested to 2.5 m) to obtain hydrostatic compensation (Dawley et al. 1975, cited in Ebel et al. 1975). Weitkamp and Katz (1973) reported that fish in waters of 123% to 143% nitrogen saturation would have to remain below a depth of 2.5 m in order to remain free of gas bubble disease symptoms. Figure 3.5 gives a pictorial representation of the relationship between surface saturation levels, exposure time, depth distribution of fish, and hydrostatic compensation.

Based on published lethal levels, the total dissolved gas concentrations in the Columbia River (i.e., reported by Clark 1977; Table 3.1) would cause significant mortality (i.e., at least 50%) within approximately 12 hours for

Table 3.2. Summary of total dissolved gas (TDG) supersaturation bioassays compiled from literature sources. (LE50 is time to lethal exposure for 50% of individuals tested.)

Species	Supersaturation Level	Lethal Exposure Time	Reference
Sockeye salmon	116.7% TDG	LE50 in 96 h	Nebeker and Brett (1976)
Rainbow trout	130% N ₂ for 16 h/d	LE50 in 16-70 h	Blahm et al. (1973) cited in Weitkamp and Katz (1980)
Cutthroat trout	116% TDG	LE50 in 89 h	Fickeisen and Montgomery (1978)
	120% TDG	LE50 in 34 h	
	124% TDG	LE50 in 17 h	
	128% TDG	LE50 in 12 h	
	110-127% TDG	LE50 in 14 d	May (1973)
Mountain whitefish	125-131% TDG	LE50 in 2.2 d	
	116% TDG	LE50 in 48 h	Fickeisen and Montgomery (1978)
	120% TDG	LE50 in 50 h	
	124% TDG	LE50 in 14 h	
	128% TDG	LE50 in 12 h	
	116-127% TDG	LE50 in 12 d	May (1973)
Northern squawfish	120% TDG	LE50 in 9.7 d	Bentley et al. (1976)
	126% TDG	LE50 in 20 h	
Largescale sucker	120% TDG	LE50 in 103 h	Fickeisen and Montgomery (1978)
	124% TDG	LE50 in 67 h	
	128% TDG	LE50 in 34 h	
Stoneflies	125% TDG	LE50 not achieved	Nebeker et al. (1976)
Daphnia sp. non-egg-carrying adults	120% TDG	LE50 in 91 h	Nebeker et al. (1976)
	130% TDG	LE50 in 65 h	
	140% TDG	LE50 in 71 h	

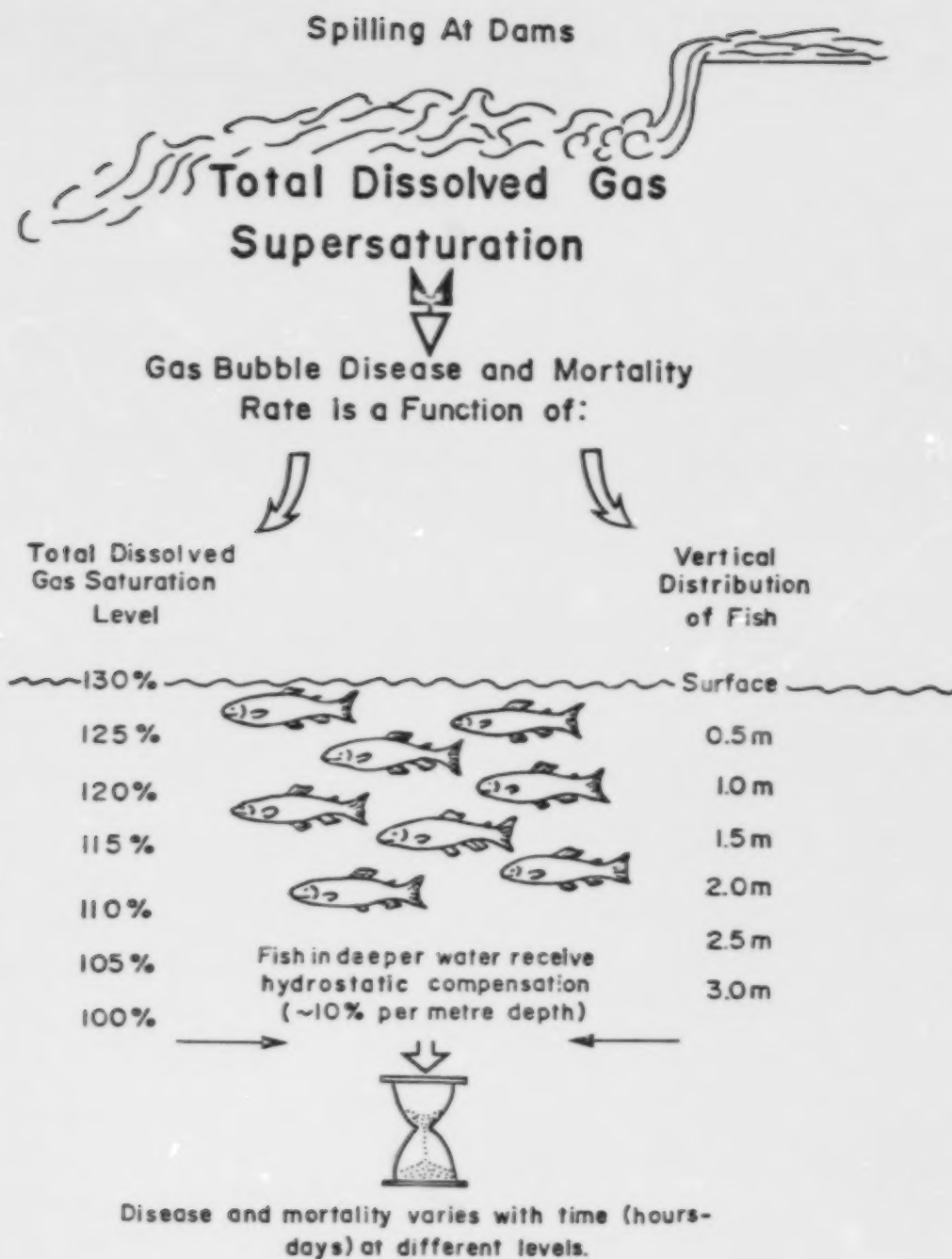


Figure 3.5. Generalized representation of cause and effect relationship in gas supersaturation-gas bubble disease-fish mortality (adapted from Ebel et al. 1975).

salmonids and whitefish held near the surface, and within 34 hours for suckers, during most of the summer months. It is likely, however, that the fish in the Columbia River usually can avoid gas supersaturation problems by remaining in deep water throughout most of the day.

Dissolved oxygen levels in the Columbia and Kootenay rivers are high (Table 3.3). The saturation levels of dissolved oxygen contribute to the high TDG saturation levels occurring in the system throughout much of the year. IEC (1981) indicated that no appreciable oxygen sag (i.e., reduction in dissolved oxygen concentrations due to oxidation of materials in the water) occurs in the section in the Columbia River between the BC Timber Ltd.^a outfall and Birchbank.

3.1.1.2 Chemical

The water quality study for the Murphy Creek project (IEC 1981) examined selected chemical parameters in the Columbia and Kootenay rivers at three sites in the study area (downstream of the Hugh Keenleyside Dam, downstream of the Brilliant Dam, and at Birchbank). Mean concentrations (usually based on a minimum of 30 samples) were reported for various species of nitrogen and phosphorous. The ranges in average concentration among the three sites for the nitrogen species were as follows: ammonia N—0.007 to 0.009 mg/L; nitrite/nitrate N—0.055 to 0.124 mg/L; organic N—0.059 to 0.09 mg/L; total Kjeldahl N—0.068 to 0.105 mg/L; and total N—0.130 to 0.192 mg/L. The ranges in average concentration of orthophosphate and total phosphorus (as P) were reported as 0.003 to 0.0058 mg/L and 0.0067 to 0.013 mg/L, respectively.

IEC (1981) also concluded that trace metal concentrations in the Columbia River within the study area are low and that there is no indication of trace metal contamination within this section.

^aformerly Canadian Cellulose Company Limited

Table 3.3. Summary of dissolved oxygen levels in the study area, 1976 to 1979 (from IEC 1981).

Location	Average Dissolved Oxygen (mg/L)	Percent Saturation			Sample Size
		Avg.	Max.	Min.	
Columbia River at Hugh Keenleyside Dam	11.34	97	122	82	25
Kootenay River at Brilliant Dam	11.58	100	120	87	25
Columbia River at Birchbank	11.59	98	114	83	25

Several effluents enter the river at Castlegar but the largest discharge is from BC Timber Ltd. (contributing 99% to the effluent inputs at Castlegar). The effluent is released into the Columbia River mainstem at the rate of approximately $1.4 \text{ m}^3/\text{s}$. A study that examined the impact of the effluent on water quality indicated only a localized effect within a 6-km section downstream of the discharge (Beak Consultants Ltd. 1980). The effluent, however, affects local fishing practices. Many local fishermen evidently refuse to angle below the discharge, due to the "peculiar" odour and taste of specimens captured. Angler avoidance also has been reported to occur on the upper Kootenay River in the area near the Crestbrook pulp mill at Skookumchuck (B.C. Ministry of Environment 1977).

At the downstream end of the study area, Cominco Ltd. at Trail is a major effluent source but will be below the proposed dam. The B.C. Ministry of Environment (unpublished data) documented that higher concentrations of heavy metals occur in sediments downstream of the plant discharge channel (Table 3.4). Between 18 and 23 March 1980, Cominco Ltd. had a mercury spillage into the Columbia River (R. Crozier, B.C. Waste Management Branch, pers. comm.). Mercury levels found in fish muscle tissue from specimens caught on 5 and 6 August 1980 are presented in Table 3.5. The mercury concentrations for fish species tested were generally below the legal limit set by the Canadian Government for commercially sold fish (i.e., less than $0.5 \text{ } \mu\text{g/g}$ wet weight; Hearnden 1970); northern squawfish were the exception. One specimen that was caught 8 km upstream of Trail had a mercury concentration of $0.79 \text{ } \mu\text{g/g}$. Two of four northern squawfish caught 16 km downstream of the Cominco Ltd. outfall were above the $0.5 \text{ } \mu\text{g/g}$ limit, having levels of $0.70 \text{ } \mu\text{g/g}$ and $0.86 \text{ } \mu\text{g/g}$, respectively.

3.1.2 BENTHIC INVERTEBRATES

Little information exists on the benthic invertebrate fauna of the Columbia River in the study area. Beak Consultants Ltd. (1980) examined the benthic fauna in relation to the effluent from Canadian Cellulose Ltd. (now BC Timber Ltd.). In a localized region within 6 km of the discharge site, they documented a reduction in the proportion of pollution intolerant

Table 3.4. Mean heavy metal concentrations found in sediment samples from the Columbia River, 24 April 1980 (B.C. Ministry of the Environment, unpublished data).

Location	Bank	Parameter				
		Mercury ($\mu\text{g/g}$ at 20°C)	Arsenic ($\mu\text{g/g}$)	Cadmium ($\mu\text{g/g}$)	Copper ($\mu\text{g/g}$)	Lead ($\mu\text{g/g}$)
Km 19.5 - upstream of Stoney Creek	R ^a	0.06	< 5.0	< 1.0	12.3	29.0
	L ^b					825.7
Km 17.0 - discharge channel (Sewer #08)	R	572.0	1075.5	173.0	2020.0	25500.0
	L					14150.0
Km 16.2 - upstream of old Trail Bridge	R	8.1	89.7	16.0	1956.7	2290.0
	L	0.2	16.5	< 1.0	51.5	253.0
Km 13.2 - upstream of Bear Creek	R	6.5	37.0	6.0	636.3	1141.0
	L	1.4	23.3	1.0	292.0	198.0
Km 7.5 - downstream of Beaver Creek	R	7.14	25.0	12.7	250.0	659.0
	L	1.7	57.0	5.0	1.5	444.5
Km 1.0 - Columbia River at Waneta	R	1.3	35.7	1.7	844.7	263.0
	L	5.2	53.7	6.3	1017.0	789.0

^aR = right downstream bank

^bL = left downstream bank

Table 3.5. Concentrations of mercury in the flesh of selected species of Columbia River fish subsequent to a spill at the Cominco Ltd. plant at Trail (B.C. Ministry of Environment, unpublished data).

Location ^a	Date 1980	Species	Mean Mercury Concentration $\mu\text{g/g}$ (wet weight)	Range of Mercury Concentrations $\mu\text{g/g}$ (wet weight)	Sample Size
Km 25.0	5 Aug.	Mountain whitefish	0.11	< 0.05-0.21	8
		Rainbow trout	< 0.05		1
		Northern squawfish	0.79	0.12-0.21	1
		Largescale sucker	0.16		5
Km 16.2	6 Aug.	Rainbow trout	0.17	0.09-0.16 0.21-0.27 0.11-0.22	1
		Walleye	0.23		1
		Mountain whitefish	0.14		4
		Peamouth	0.24		2
Km 1.0	6 Aug.	Largescale sucker	0.16	0.16-0.25 0.24-0.86 0.20-0.26 0.09-0.21	7
		Yellow walleye	0.21		2
		Northern squawfish	0.52		4
		Peamouth	0.23		2
		Largescale sucker	0.16		6
		Kokanee	0.11		1

^aCominco Ltd. Sewer #08 is located at Km 17.0

organisms (e.g., mayflies, stoneflies) and an increase in the proportion of tolerant forms (e.g., oligochaetes). Downstream of the effluent, total densities increased with highest values recorded near the outfall. At sites unaffected by the effluent (i.e., upstream control sites and sites downstream of the affected zone), clean water organisms were not common (i.e., less than 10%) and the communities were dominated by moderately tolerant organisms (e.g., leaches, midges, mites, clams). Densities on the two sampling occasions ranged from about 1500 to 5000/m² but with values of about 14 000 and 27 000/m² recorded at two stations. At the downstream sites where the communities were structurally similar to upstream sites, densities generally were about 1500 to 2500/m². The elevated densities downstream of the effluent were attributed to enrichment effects of the effluent. It should be noted that regions downstream of the Beak Consultants Ltd. study area have less representation of soft substrates and a higher amount of gravel/cobble substrates, and could be expected to support higher densities of the clean-water groups of benthic organisms.

3.1.3 MYSIDS

Mysis relicta was introduced into the Arrow Lakes Reservoir in 1967 and in the early 1970's to enhance the fishery within the lakes (R. Lindsay, B.C. Fish and Wildlife Branch, pers. comm. 1978). Mysids display a diurnal migration pattern in which they move from deep waters, at dusk, to feed in the metalimnion; subsequently, they return to the bottom by pre-dawn (Beeton 1960; Gosho 1975; Morgan et al. 1978). Since they are poor swimmers and are easily transported by currents (Holmquist 1959 in Gosho 1975; Ricker 1959), it is during the period when they are in the metalimnion that they become entrained at the Hugh Keenleyside Dam, and pass over the spillway into the Columbia River.

The densities of mysids collected in the Columbia River in the present study are given in Table 3.6. Densities were typically higher close to the Hugh Keenleyside Dam and decreased progressively downstream. Mysids constitute an important food source for fish (e.g., kokanee, rainbow trout) in the river, with utilization being heaviest nearest the dam, likely accounting for the decreased densities downstream.

Table 3.6. *Mysis relicta* densities in the Columbia River below the Hugh Keenleyside Dam, 1980 and 1981.

Date	Location (km)	Time	Density (No./m ²)
1980			
7 May	51.2	2300	0
	55.5	2315	0
	56.0	2330	0
12 July	54.3	0154	118.8
	49.2	0249	25.0
	54.3	0343	40.6
11-12 Sept.	55.5	2300	150.0
	53.8	2320	108.3
	52.7	2400	25.0
	52.4	0030	66.7
	49.2	0117	13.9
1981			
6 Feb.	52.4	2130	5.6

3.2 FISH SPECIES COMPOSITION AND STATUS

During the present study, 20 species of fish were encountered in the Columbia River and its tributaries (Table 3.7). One species, the walleye, had not been reported in the literature to be in the study area. Walleye have apparently extended their range upstream from Lake Roosevelt where they are abundant (R. Duff, Washington Department of Game, Spokane, pers. comm.). Six species of fish known to be part of the Lake Roosevelt species assemblage (Table 3.8) were not captured in the present study area, probably due to their habitat requirements which differ from the habitats present within the study area. Although white sturgeon were not captured during this investigation, they do inhabit the Columbia and Kootenay rivers within the study area (i.e., based on angling records).

The general population status of the various fish species in the study area as indicated by their percentage contribution to the catch^a is summarized in Table 3.9. A total of 110 729 fish were captured from the mainstem Columbia River or observed in the mainstem during the five study intervals. Redside shiner was the dominant species, contributing 78.4% to the total (i.e., primarily individuals observed during electrofishing). Catostomids (e.g., longnose and largescale suckers) also were numerous, contributing approximately 12% to the total. Overall, coarse fish species and minnows accounted for over 90% of the catch.

Ten species of fish present in the study area are regarded as sport fish. Within this group, mountain whitefish were the most abundant (i.e., 4.7% of total catch during this study). Kokanee and rainbow trout, which are the two most preferred sport fish species in the area, contributed 0.7 and 0.1% to the catch in the mainstem, respectively. It is felt that the low catch rate for rainbow trout reflects the difficulty of sampling their preferred habitat (i.e., large eddies, deepwater habitats), rather than their actual abundance in the system.

^aIn this report, "catch" includes fish actually captured as well as fish observed while electrofishing, but not actually caught.

Table 3.7. Fish species encountered in the Columbia River and tributaries, 1980 and 1981.

Common Name	Species Code	Scientific Name
Kokanee	(K)	<i>Oncorhynchus nerka</i> (Walbaum)
Rainbow trout	(RT)	<i>Salmo gairdneri</i> Richardson
Brook trout	(BT)	<i>Salvelinus fontinalis</i> (Mitchill)
Cutthroat trout	(CT)	<i>Salmo clarki</i> Richardson
Dolly Varden	(DV)	<i>Salvelinus malma</i> (Walbaum)
Walleye	(YW)	<i>Stizostedion vitreum vitreum</i> (Mitchill)
Burbot	(LING)	<i>Lota lota</i> (Linnaeus)
Mountain whitefish	(MW)	<i>Prosopium williamsoni</i> (Girard)
Lake whitefish	(LW)	<i>Coregonus clupeaformis</i> (Mitchill)
Longnose sucker	(LNS)	<i>Catostomus catostomus</i> (Forster)
Largescale sucker	(LSS)	<i>Catostomus macrocheilus</i> Girard
Bridgelip sucker	(BLS)	<i>Catostomus columbianus</i> (Eigenmann & Eigenmann)
Carp	(CARP)	<i>Cyprinus carpio</i> Linnaeus
Redside shiner	(RSS)	<i>Richardsonius balteatus</i> (Richardson)
Northern squawfish	(NSF)	<i>Ptychocheilus oregonensis</i> (Richardson)
Peamouth	(PM)	<i>Mylocheilus caurinus</i> (Richardson)
Longnose dace	(LND)	<i>Rhinichthys cataractae</i> (Valenciennes)
Prickly sculpin	(PS)	<i>Cottus asper</i> Richardson
Torrent sculpin	(TS)	<i>Cottus rhotheus</i> (Smith)
Shorthead sculpin	(STHS)	<i>Cottus confusus</i> Bailey and Bond

Total Number of Species: 20

Table 3.8. Fish species composition in Lake Roosevelt, 1948 and 1962 to 1963.

Common Name	Scientific Name	% Composition	
		Gangmark & Fulton (1949)	Earnest et al. (1966) 1962-63
Cypriniformes			
Carp	<i>Cyprinus carpio</i>	0.5	0.3 ^a
Chiselmouth	<i>Acrocheilus alutaceus</i>	NC	0.2
Northern squawfish	<i>Ptychocheilus oregonensis</i>	59.9	25.6
Peamouth	<i>Mylocheilus caurinus</i>	22.5	46.3
Redside shiner	<i>Richardsonius balteatus</i>	5.4	1.0
Suckers	<i>Catostomus</i> sp.	7.2	19.4
Tench	<i>Tinca tinca</i>	0.9	-
Total		96.4	92.8
Perciformes			
Largemouth bass	<i>Micropterus salmoides</i>	NC	NC
Smallmouth bass	<i>Micropterus dolomieu</i>	NC	0.1
Yellow perch	<i>Perca flavescens</i>	2.2	3.9
Sculpins	<i>Cottus</i> sp.	0.5	
Pumpkinseed	<i>Lepomis gibbosus</i>	0.9	0.1
Walleye	<i>Stizostedion vitreum vitreum</i>	- ^b	-
Total		3.6	4.1
Salmoniformes			
Dolly Varden	<i>Salvelinus malma</i>	NC	0.3
Kokanee	<i>Oncorhynchus nerka</i>	NC	0.6
Cutthroat trout	<i>Salmo clarki</i>	NC	-
Brook trout	<i>Salvelinus fontinalis</i>	NC	0.1
Rainbow trout	<i>Salmo gairdneri</i>	NC	1.1
Lake whitefish	<i>Coregonus clupeaformis</i>	-	0.2 ^c
Mountain whitefish	<i>Prosopium williamsoni</i>	NC	0.9
Total		0	3.2

NC - not captured during this survey but known to be present

- - presence in area unconfirmed

^a carp are known to be present in much higher numbers than indicated^b Mr. R. Morgan (pers. comm.) noted that in 1980 walleye contributed approximately 25% to the catch (in samples from lake)^c Mr. R. Morgan (pers. comm.) noted that in 1980 lake whitefish contributed approximately 5.3% to the catch (in samples from lake)

Table 3.9. Numbers of fish captured or observed by various sampling methods and percentage composition of total catch (by species) in the mainstem Columbia River, 1980 and 1981.

Species	Night		Day	Gill Net	Seine	Set Line	Minnow Trap	Total	
	Electrofishing	Electrofishing						No.	%
K	707		2	12				721	0.7
RT	72		23	22	16			133	0.1
BT			1					1	< 0.1
DV	13			2				15	< 0.1
YW	6		1					7	< 0.1
LING	125			1		6		132	0.1
MW	4711		301	20	125			5157	4.7
LW				11				11	< 0.1
Suckers ^a	6953		417		5535			12905	11.7
LNS	116		5	20	1			142	0.1
LSS	106		173	34	1			314	0.3
BLS	5		6	2				13	< 0.1
CARP	2							2	< 0.1
RSS	86625		50		134		1	86810	78.4
NSF	184		6	32		1		223	0.2
PM	1640		1	31	4			1676	1.5
Sculpins	2275		156		35		1	2467	2.2
Totals	103540		1142	187	5851	7	2	110729	

^a observed, not identified by species

Numbers of fish caught and catch per unit effort (CUE) for each of the seasonal sample periods are summarized by capture method in Tables 3.10 to 3.13. Detailed summaries of catch and CUE for each sample site are provided in Appendices A to C.

3.3 MAJOR SPORT FISH SPECIES

3.3.1 KOKANEE

Kokanee are a landlocked form of the anadromous sockeye salmon. In the Columbia River system, natural populations of kokanee existed in the Arrow and Kootenay lakes prior to hydroelectric development of the Canadian section of the system. At present, kokanee populations remain in both of these systems; they also are present in the Columbia River within the study area, and in Lake Roosevelt in Washington (R. Duff, pers. comm.).

The majority of kokanee in the Columbia River within the study area likely are fish that have been transported out of the Arrow Lakes Reservoir, or fish that have migrated upstream from Lake Roosevelt to spawn. This aspect will be discussed in the following sections.

3.3.1.1 Distribution and Abundance

During the present study, a total of 721 kokanee were either captured or observed in the mainstem Columbia River; they contributed 0.7% to the total catch by all sample methods (Table 3.9). All kokanee were captured in the upper reaches (i.e., Km 45 to Km 56.2) of the Columbia River.

There is little information available in the literature regarding the life requisites of kokanee in large river systems. This species characteristically occupies the open water portion of lakes; they move to inshore areas or streams to spawn during the fall. In the Columbia River kokanee were most abundant above Castlegar; in this section the river is wide, deep, and slow flowing, an environment in many ways similar to the natural lake habitat of kokanee. In contrast, the higher gradient and swift flow of the Columbia River from Castlegar to Trail apparently does not provide the necessary habitat requirements for kokanee. The results of a creel survey undertaken

Table 3.10. Night electrofishing catch and CUE (No. fish/km) for all sample sections in the mainstem Columbia River, 1980 and 1981.

Period	Distance (km)	Number ^a and CUE															Total Fish CUE	
		VW	K	RT	BT	DV	HW	Suckers ^b	LNS	LSS	BLS	CARP	LING	Sculpin	NSF	PH		RSS
Spring 29 April-11 May	5.5 km		95 17.3	24 4.4		3 0.5	34 6.2		12 2.2	9 1.6			6 1.1	2 0.4	5 0.9		211 30.4	401 72.9
Summer 11-18 July	21.3 km		567 26.6	41 1.9		2 0.1	1652 77.6	1071 50.3	69 3.2	52 2.4	4 0.2		34 1.6	349 16.4	35 1.6	1629 76.5	23124 1085.6	28629 1344.1
Fall 26 Aug.-11 Sept.	22.0 km	5 0.2	43 2.0	3 0.1		4 0.2	2252 102.4	4168 189.5	32 1.5	42 1.9	1 0.1	1 0.1	83 3.8	686 31.2	23 1.0	11 0.5	42564 1934.7	49918 2269.0
Winter 29 Jan.-6 Feb.	8.7 km	1 0.1				4 0.5	66 7.6	47 5.4	3 0.3	3 0.3				7 0.8	1 0.1		476 54.7	608 69.9
Total CUE	57.5 km	6 0.1	705 12.3	68 1.2		13 0.2	4004 69.6	5286 91.9	116 2.0	106 1.8	5 0.1	1 0.1	123 2.1	1044 18.2	64 1.1	1640 28.5	66375 1154.3	79556 1383.6

^aTotal fish encountered (captured and observed).^bObserved; not identified to species.

Table 3.11. Day electrofishing catch and CUR (No. fish/km) for all sample sections in the mainstem Columbia River, 1980 and 1981.

Period	Distance (km)	Number ^a and CUR																Total Fish (CUR)
		YW	K	RT	BT	DV	HW	Suckers ^b	EMS	LSS	BL5	LH6	Sculpin	NSP	PH	RSS	CARP	
Spring 29 April-11 May	9.1 km			5	0.5		22		5	16				3				58
							2.4		0.5	1.8				0.3				5.6
Summer 11-18 July	12.9		1	10	0.8		17	37		38	2		2	1				111
			0.1				1.1	2.9		2.9	0.2		0.4	0.1				8.6
Fall 26 Aug.-11 Sept.	18.1	1	1	8	1		262	380		119	6		151	2	1	50		988
		<0.1	<0.1	0.4	<0.1		14.5	21.0		6.6	0.2		8.1	0.1	<0.1	2.8		56.1
Winter 29 Jan.-6 Feb.	0																	
Total CUR	60.1	1	2	23	1		301	417	5	173	6		156	6	1	50		1142
		<0.1	<0.1	0.6	<0.1		7.5	10.4	0.1	4.1	0.1		3.9	0.2	<0.1	1.2		28.9

^aTotal fish encountered (captured and observed).^bObserved; not identified to species.

Table 3.12. Gillnet catch and CUE (No. fish/100 m²/24 h) for all sample sites in the mainstem Columbia River, Spring to fall 1980 and winter 1981.

Period	Set Duration (h)	Net Area (m ²)	Number and CUE											Total (CUE)
			K	RT	DV	MC	LM	LHS	LSS	BLS	LING	HSP	PM	
Spring 29 Apr.-11 May	77	100	6 1.7	11 3.1	1 0.1	5 1.4	2 0.6	20 5.7	31 8.9			22 6.3	28 8.0	126 36.1
Summer 11-18 July	55.2	180		1 0.2					2 0.5	2 0.5		2 0.5	2 0.5	9 2.2
Fall 26 Aug.-11 Sept.	53.3	144	2 0.6	7 2.2		1 0.3						3 0.9	1 0.3	14 4.4
Winter 29 Jan.-6 Feb.	191.4	180	4 0.1	3 0.2	1 0.1	14 1.0	9 0.6		1 0.1		1 0.1	5 0.3		38 2.6
Total CUE	376.9 $\bar{x} = 154$		12 0.5	22 0.9	2 0.1	20 0.8	11 0.5	20 0.8	34 1.4	2 0.1	1 0.1	32 1.3	31 1.3	187 7.7

Table 3.13. Beach seine catch and CUE (No. fish/100 m²) for sites in the mainstem Columbia River 1980 and 1981.

Period	No. Hauls	Area Sampled (m ²)	Number and CUE								Total CUE
			RT	MW	Suckers ^a	LNS	LSS	Sculpin ^a	PM	RSS	
Spring 29 Apr.-11 May	18	1760	1 <0.1	124 7.0		1 <0.1	7 0.4	1 0.1	2 0.1	136 7.7	
Summer 11-18 July	21	1925	14 0.7	1 <0.1	5249 272.7		3 0.2		2 0.1	5269 273.7	
Fall 26 Aug.-11 Sept.	18	1750	1 <0.1		286 16.3		25 1.4	3 0.2	130 7.4	445 25.4	
Winter 29 Jan.-6 Feb.	12	1540				1 <0.1				1 <0.1	
Total CUE	69	6975	16 0.2	125 1.8	5535 79.4	1 <0.1	35 0.5	4 0.1	134 1.9	5851 83.9	

^a not identified to species

by the B.C. Fish and Wildlife Branch within the study area indicate a distribution of kokanee similar to that determined in this study. Local anglers reported only incidental catches of kokanee in the Columbia River downstream of Castlegar. Upstream of Castlegar, kokanee were a common component of the catch (B.C. Fish and Wildlife Branch 1981, Appendix H).

Night electrofishing results in the Columbia River above Castlegar indicated a seasonal shift in kokanee abundance (Figure 3.6). Catch per unit effort (CUE) for kokanee was 17.3 fish/km in the spring (1980) and 26.6 fish/km during the summer. The CUE fell to 2.0 fish/km during the fall, zero during the winter sample period, and 0.2 fish/km during the spring (1981) sample period. The low fall, winter, and spring (1981) CUE and the low catch by anglers during the winter of 1980-1981 suggests that a substantial reduction in kokanee abundance has occurred. This is further supported by the lack of angler success for this species during the late winter and spring of 1981 (B.C. Fish and Wildlife Branch 1981). The reasons for the decreased abundance are not clear but could be the result of:

- (a) decreased recruitment into the Columbia River population from declining stocks in the Arrow Lakes or
- (b) high levels of dissolved gases in the water (resulting from spillway discharge at the Hugh Keenleyside dam) which would:
 - (i) force the kokanee to occupy depths less accessible to sampling thereby decreasing sampling efficiency;
 - (ii) force fish out of the area; or
 - (iii) cause direct mortality.

A population estimate for kokanee was attempted utilizing the Petersen mark-recapture method (Ricker 1971); however, due to the limited number of recaptures a valid estimate could not be formulated. As an alternate method, catch per unit effort data obtained during the summer 1980 night electrofishing surveys were used to generate an estimate. It should be noted that the numerical estimates may be subject to considerable imprecision due to the difficulty in quantitatively sampling a large river system and converting CUE data to actual population values. The estimate was derived by the following formula:

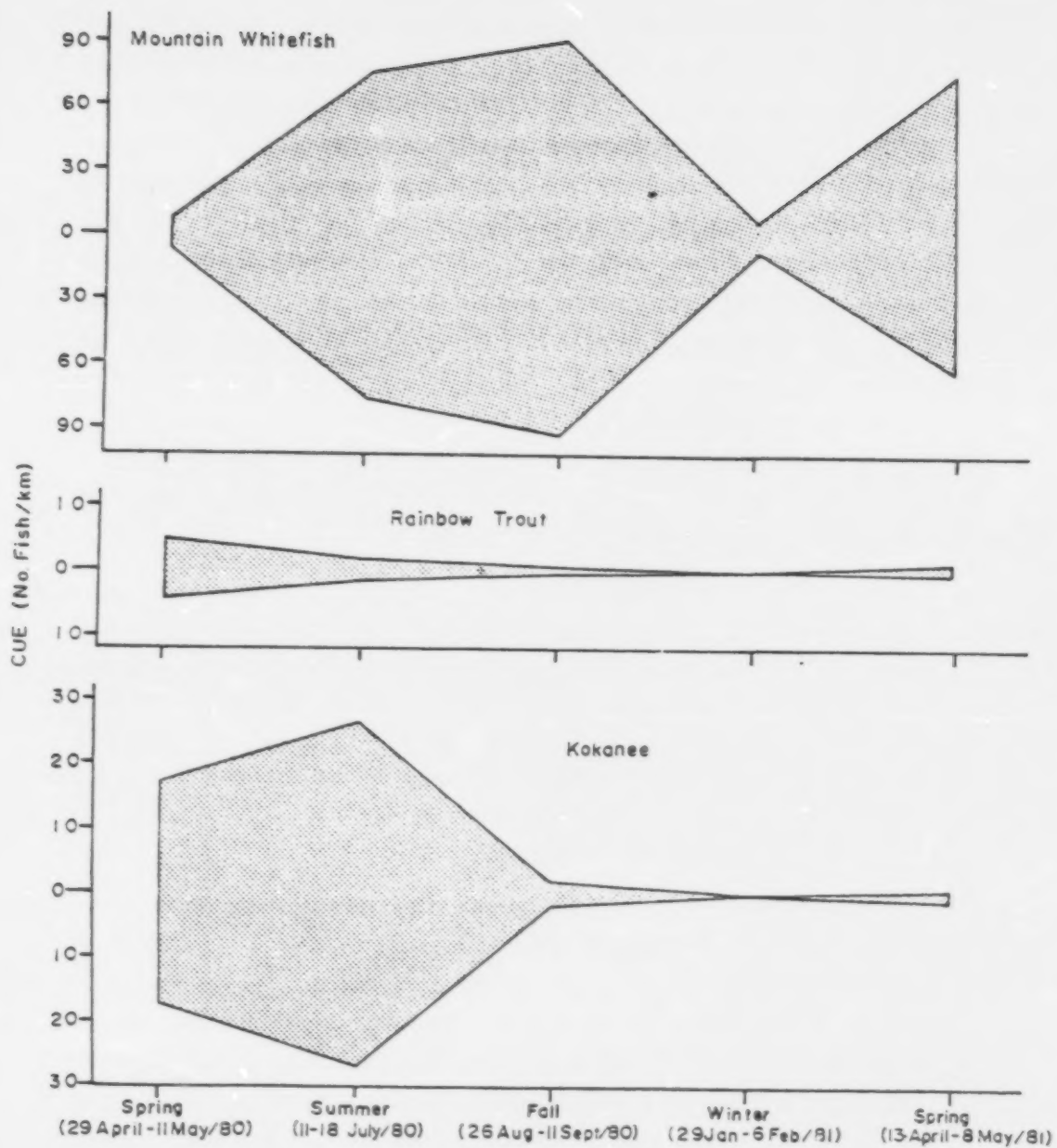


Figure 3.6. Seasonal variation in night electrofishing catches for major sport fish species in the Columbia River, 1930 and 1931.

$$\text{Numbers of kokanee/section} = (C + O)/\text{Section} \times \frac{W}{E}$$

where: $(C + O)/\text{Section}$ = Numbers of kokanee captured and observed in each electrofishing section;

W = The mean width of one-half of the river channel (i.e., portion within and adjacent to electrofishing effort);

E = The effective sampling width of the electrofisher.

Several assumptions were made with respect to the derivation and use of this formula. These are:

- (1) The estimate is only for kokanee age 2+ or older (i.e., younger fish could not be accurately separated from other salmonids in the observed sample).
- (2) The estimate was based on the summer electrofishing capture rates which were the highest recorded; therefore, the estimate indicates the maximum value that would be calculated from electrofishing data.
- (3) Each electrofishing section was considered to extend from the bank to the middle of the channel to account for reaches sampled along both banks.
- (4) Fish distribution was assumed to be uniform throughout each section (i.e., longitudinally and cross-sectionally). The validity of this assumption is not known since kokanee have been reported to undergo inshore movements during the evening (see Section 3.3.1.2 below). The shoreward movement may result in an even distribution of fish in the available habitat (i.e., inshore area likely not used during the day due to high light intensity), or in a concentration of fish in the sampled inshore areas. If the latter is true, the estimate of abundance would be higher than the actual abundance.
- (5) Kokanee movements into or out of the sample sections did not occur over the duration of the survey period.
- (6) All kokanee within the range of the electrofisher were captured or observed. Although this assumption is likely not true, a conservative value for the effective width of the electrofisher

was used (i.e., 5 m), thereby compensating somewhat for fish missed within the surrounding area.

The estimated numbers of kokanee in sample sections upstream from the Castlegar ferry in the summer of 1980 are presented in Table 3.14. The total population of kokanee in the 7.2-km section was estimated at 9800 fish. This figure provides only a rough estimate of the abundance of kokanee in the study area; its limitations should be recognized.

In general, kokanee were more abundant in sample sections situated along the north bank of the river. The lower numbers recorded along the south bank may reflect the activities of BC Timber Ltd. in this area (i.e., log booms, effluent discharge, etc.).

3.3.1.2 Movement Patterns

The majority of kokanee were captured during night electrofishing surveys; only two were captured by day electrofishing (Table 3.11). This indicates the occurrence of vertical and shoreward feeding movements during the evening, possibly influenced by food availability and light intensity (Lorz and Northcote 1965; Scott and Crossman 1973).

A total of 145 kokanee were marked and released (62 tagged, 83 fin clipped) in the mainstem Columbia River upstream from the Kootenay River confluence. Of these, only two fin-clipped individuals were recovered by the field crew (Appendix D). Both of these fish were marked and recaptured upstream from Castlegar during the July sample period. An additional three kokanee were recaptured by anglers, but exact recapture location is not known. Although tag-recapture data provided no evidence of extensive kokanee movements in the Columbia River, R. Duff (pers. comm.) suggested that kokanee from Lake Roosevelt may be migrating north into Canadian reaches of the Columbia River to spawn. In support of this theory, he cites the presence of kokanee spawners at the inlet of the Columbia River to Lake Roosevelt during the August to November period, and the limited availability of suitable spawning habitat in Lake Roosevelt and surrounding tributaries. Kokanee adults in Lake Roosevelt generally range from 380 to 560 mm in fork length. Adult spawners in Norns Creek ranged from 382 to 493 mm in

Table 3.14. Estimated numbers of kokanee in various electrofishing sections on the Columbia River, 11-18 July 1980.

Section	Mean Numbers Captured ^a	Effective Sampled Width (m)	Mean Channel Width (m)	Extrapolation Factor	Estimated No./ Sample Section
ES-18	49	5	320	32	1580
ES-19	163	5	340	34	5560
ES-20	46	5	300	30	1380
ES-21	10	5	280	28	280
ES-22	0	5	260	26	0
ES-26	3	5	360	36	110
ES-27	5	5	300	30	150
ES-28	5	5	320	32	160
ES-29	0	5	360	36	0
Log boom section ^b	18	5	300	30	540

Estimated Total = 9800(+ 50%)

^a includes mean number captured and observed during the 11-18 July 1980 sample period

^b not electrofished; numbers extrapolated from catches in sections upstream and downstream

length ($n = 9$), and were considerably larger than mature adults captured in the mainstem upstream of Norns Creek (range 210 to 360 mm, $n = 10$). Due to the size similarity between kokanee in Lake Roosevelt and in Norns Creek, it is conceivable that the latter stock are not resident in the area and may be migrants from Lake Roosevelt. The absence of larger individuals from angler catches in the upper reaches of the Columbia River during most of the year provides further evidence that they are not year-round residents in this section of the river.

An alternative hypothesis is that the kokanee spawning in Norns Creek are resident in the study area but were not captured by the sampling methods utilized. However, this assumes that these particular fish have certain behavioural characteristics (i.e., residing in deeper, mid-channel areas of the river, with no onshore movements) that have allowed them to remain undetected by the sampling program.

The smaller kokanee which inhabit the upper sections of the Columbia River likely originate from Lower Arrow Lake. Mature kokanee captured in the fall 1980 survey below the Hugh Keenleyside Dam were similar in size to kokanee observed on 10 September 1980 in the spawning run in Deer Creek (a tributary to Lower Arrow Lake). Kokanee which are transported out of the Arrow Lakes Reservoir over the Hugh Keenleyside Dam may become established in the slow-moving upper reaches of the Columbia River. Others may move downstream into Lake Roosevelt as suggested by Earnest et al. (1966). The existence of two distinct populations of kokanee in the study area is supported by scale studies (Section 3.3.1.6(d)). These analyses indicated that the number of circuli to first annulus was different between Columbia River kokanee and Norns Creek kokanee. This further suggests that Norns Creek fish may be moving into the study area from downstream regions.

3.3.1.3 Spawning

In 1980, adult kokanee were encountered only in the upper sections of the Columbia River, in Norns Creek, and in Murphy Creek. The B.C. Fish and Wildlife Branch has records of kokanee spawning in the lower reaches of three major creeks (Norns, Murphy, and China creeks) within the study area

(Table 3.15) (P. Stent, B.C. Fish and Wildlife Branch, Trail, pers. comm.). The absence of kokanee from China Creek in 1980 may be due to:

- (a) the low adult spawning escapement into the stream in 1976 and 1977;
- (b) possible low survival of the broods in these years; or
- (c) the inability of spawners to ascend this stream in 1980 because of low water levels.

In 1980, the kokanee spawning period within the study area extended from mid August to mid-September. Spawning generally occurs in November in Lake Roosevelt (R. Duff, pers. comm.); however, spawners have been recorded as early as August and as late as February. Movement of kokanee into spawning streams has been reported to occur over a wide range of water temperatures (10.5° to 5.0°C), turbidity levels (turbid to clear), and water levels (Scott and Crossman 1973). In Norns Creek the majority of spawning occurred on sediment-free substrate ranging from 10 to 80 mm in diameter and in water depths of approximately 30 cm. Surface velocity averaged 0.5 m/s. Primary kokanee spawning locales noted in Norns Creek during the 1980 fall survey are shown in Figure 3.7.

In the mainstem Columbia River above Castlegar, suitable spawning substrate (observed to depths of 5 m) is limited. However, kokanee have been reported to spawn on lakeshores in water depths up to 10 m (Scott and Crossman 1973), which indicates spawning use of a wide range of habitats.

Escapement

The largest observed kokanee spawning run in the study area occurred in Norns Creek. An estimated 2000 kokanee spawners utilized this stream between 27 August and 11 September 1980 (Table 3.16). The lower estimates recorded on the 2 September survey may have resulted from freshet conditions which decreased visibility and counting accuracy. Kokanee were distributed throughout the creek from the mouth to the base of an impassable falls at Km 2.2; however, in all three surveys, highest densities were recorded in Reach B (Table 3.16). Historical records of escapement into Norns Creek have indicated up to 5000 kokanee spawning in the lower 2.2 km (Table 3.15).

Table 3.15. B.C. Fish and Wildlife Branch estimates of kokanee escapements in tributaries of the Columbia River, 1976 to 1980 (P. Stent, pers. comm.).

Year	Number of Kokanee		
	Norns Creek	Murphy Creek	China Creek
1976	1000		
1977	5000	50	50
1978	2500		50
1979	1500		
1980	2000		

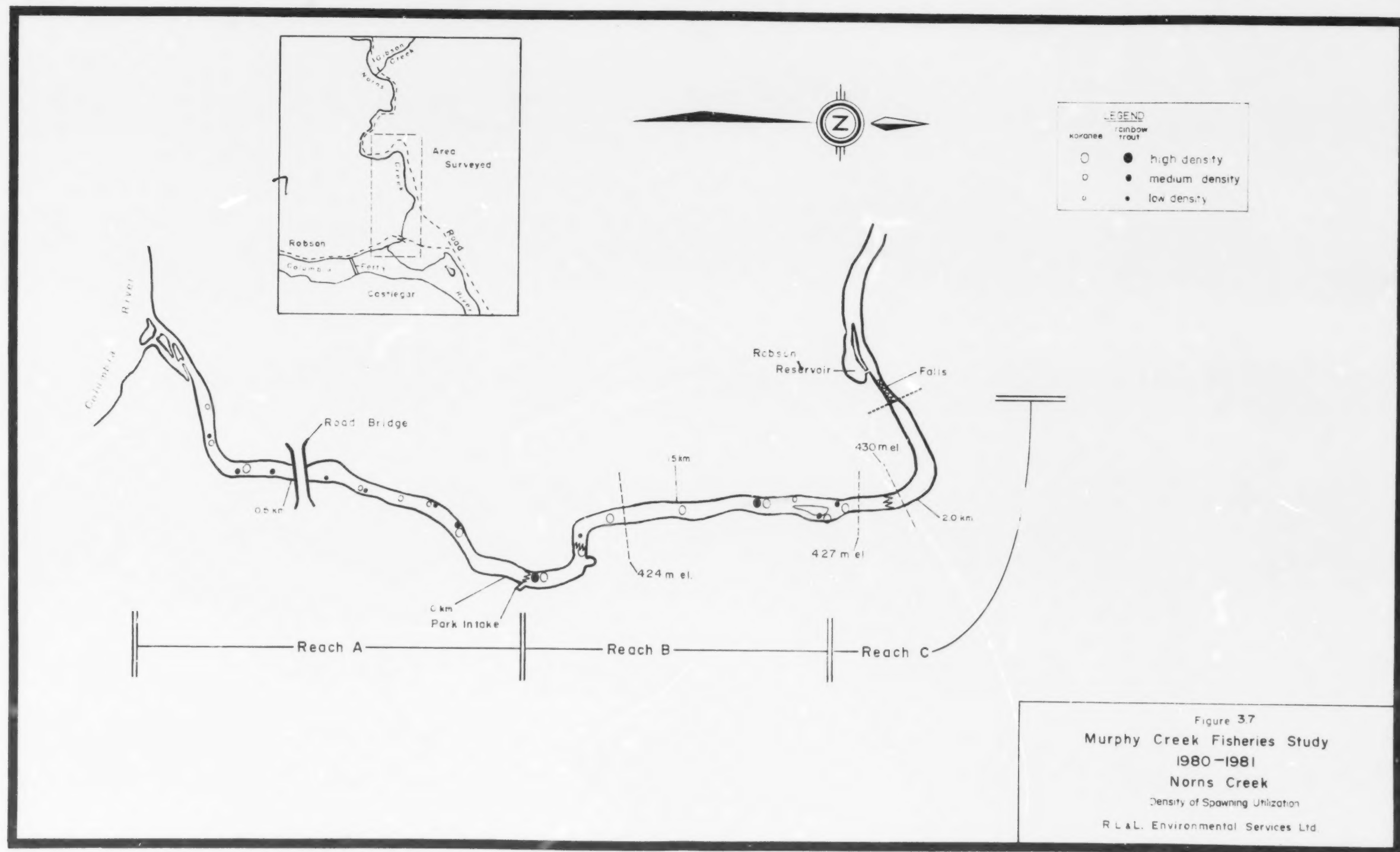


Table 3.16. Numbers of kokanee spawners enumerated in Norns Creek in 1980.

Date	Water Conditions	Water Temp. (°C)	Location and Numbers ^a			Total
			Reach A (Km 0.0-1.1)	Reach B (Km 1.1-1.8)	Reach C (Km 1.8-2.2)	
27 Aug.	Base flow High water clarity	13	470-520 (29)	1300-1390 (27)	100-110 (0)	1870-2020 (56)
2 Sept.	Freshet flows Decreased visibility	11	290-320 (27)	870-1020 (15)	200-230 (0)	1360-1570 (42)
11 Sept.	Receding flows Increased clarity	12	90-100 (37)	180-200 (18)	20-30 (0)	290-330 (55)

^a the number of carcasses observed is given in brackets

Only five kokanee spawners were observed in Murphy Creek in 1980, compared to 50 kokanee enumerated in the creek in 1977 (Table 3.15). In 1977, 10 000 kokanee eggs were planted in Murphy Creek (H. Andrusak, pers. comm.), and the five kokanee observed in 1980 may represent successful production from these eggs or progeny from the natural runs. Although actual spawning was not observed in Murphy Creek during 1980, the adults observed were holding in a pool below the highway culvert and in the adjacent water intake pond. They likely spawned in the vicinity of these holding areas.

The extent of kokanee spawning in the mainstem Columbia River is unknown. The presence of gravid and ripe kokanee in the Columbia River upstream of Norns Creek suggests that mainstem spawning may occur. However, the absence of young-of-the-year kokanee and the presence of only small numbers of yearlings in the samples from the area may indicate a low spawning use or success in the mainstem. Alternatively, it may indicate the rearing of juveniles elsewhere (i.e., possibly Lake Roosevelt) or inefficiency of sampling methods for young-of-the-year and yearlings.

3.3.1.4 Rearing

In the upper section of the mainstem Columbia River, juveniles^a represented approximately 65% of the total number of kokanee caught or observed. The absence of young-of-the-year kokanee in the catch indicates that fish of this age class either rear in other areas of the Columbia River system or that the sampling methods utilized were unable to detect their presence.

3.3.1.5 Feeding

The stomach contents of 17 kokanee ranging in size from 200 to 443 mm were examined; six (35%) of the stomachs were empty or contained only a trace of digested matter. The average stomach fullness was 30%. The diet of kokanee in the upper section of the Columbia River consisted of a

^aClassification based on size.

variety of food organisms. Mysids were the most prevalent item, occurring in nine stomachs and composing 41.3% of the total food content (Table 3.17). Zooplankton, found in three stomachs, contributed 38.5% to the total food content. Aquatic insects (caddisflies and mayflies) also were recorded as prey items. The abundance of available food items, particularly mysids coming from Lower Arrow Lake through the Hugh Keenleyside Dam, apparently provides good feeding conditions in the upper section of the Columbia River. Stomach analysis of 42 kokanee captured in January through March 1976 indicated mysids contributed 99.9% to the total food content at that time (Lindsay 1976).

3.3.1.6 Life History

A total of 208 kokanee were sampled for life history information during the 1980-1981 surveys; of these, 96% (n = 199) were captured in the Columbia River. The remaining specimens were collected from Norns Creek.

(a) Size Distribution

The mean fork length of kokanee collected from the Columbia River was 233 mm (n = 198; S.D. = 60.2); the range of sizes encountered was 85 to 469 mm. The most abundant size classes were the 200 to 220 mm and 220 to 240 mm classes (25% and 19%, respectively). The mean fork length of Norns Creek specimens was 457 mm (n = 9; S.D. = 35.5); the range was 382 to 493 mm. The heaviest kokanee weighed 1840 g. No sex-related differences in size were noted.

(b) Length-Weight Relationships

The length-weight relationship for kokanee captured in the mainstem Columbia River during this study is expressed by the equation:

$$W = (1.02 \times 10^{-5}) \times L^{3.029} \quad (n = 103, r^2 = 0.98)$$

where: W = weight in grams;

L = fork length in millimetres;

Table 3.17. Kokanee stomach content analysis, 1980.

No. of Stomachs Examined	Empty Stomachs	Average Fullness	Occurrence (No. of stomachs) and Percent of Total Volume				
			Caddisfly Larvae	Mayfly Larvae	Mysids	Zoo- plankton	Unident. Insects
17	6	30%	(3) 3.8	(2) 10.6	(9) 41.3	(3) 38.5	(3) 2.9
							(3) 2.9

n = sample size; and
 r^2 = the coefficient of determination.

The length-weight relationship for kokanee captured in Norns Creek during the fall of 1980 was:

$$W = (3.93 \times 10^{-5}) \times L^{2.833} \quad (n = 9; r^2 = 0.887).$$

(c) Age-Length Relationships

Age-length data indicate that kokanee captured in the mainstem Columbia River tend to be similar in size to kokanee from a number of waterbodies in British Columbia (Table 3.18).

Scales were examined to determine time of annulus formation. Scale samples from 20 kokanee captured between early to mid-May were viewed; of these, only one (5%) was judged to have an annulus at the scale edge. Forty-nine kokanee scale samples, each showing a minimum of two annuli, were taken during the period 11 July to 14 July 1980. Of these scale samples, 34 (69%) were considered to have recently laid down annuli. There appeared to have been some new growth beyond the last annulus in seven of these fish. All scale samples from August-caught kokanee had new growth beyond the 1980 annulus, except those displaying obvious resorption. From these determinations, it appears that most kokanee in the Columbia River within the study area form an annulus during late June to mid-July. Bjornn (1961), in a study of the Priest and Upper Priest lakes in Idaho, reported that kokanee in their second and third years of life formed an annulus in June; older fish did not form an annulus until July.

Time of annulus formation in kokanee has a greater influence on length-at-age values than for species which form an annulus in the early spring. For example, a kokanee assigned an age of 2+ in June would be assigned an age of 3+ in August; thus, care must be taken when comparing length-at-age data. To avoid this problem during the present study, ages were adjusted to correspond to the calendar year, so that a fish with two annuli in June (i.e., prior to annulus formation) was aged as a 3-year-old.

Table 3.18. Comparison of age-length data for kokanee from the Columbia River (1980 and 1981) and various locations within British Columbia (1976 to 1978). $\bar{x}$ = mean fork length (mm) and n = sample size.

Location		Age				
		1+	2+	3+	4+	5+
A. Columbia River ^a	$\bar{x}$	114	195	249	311	392
	n	10	17	65	5	1
B. Kootenay Lake ^b						
	North Arm 1977	$\bar{x}$	-	197	216	
		n	-	19	19	
	North Arm 1978	$\bar{x}$	-	205	232	410
		n	-	46	237	15
	South Arm 1977	$\bar{x}$	-	190	203	
		n	-	10	5	
	South Arm 1978	$\bar{x}$	-	203	229	
		n	-	70	26	
	West Arm 1977	$\bar{x}$	-	258	301	
		n	-	69	33	
	West Arm 1978	$\bar{x}$	-	283	257	321
		n	-	169	92	8
C. Otter Lake 1976-77 ^c	$\bar{x}$	170	175	209	212	
	n	1	1	9	4	
D. Arctic Lake 1976-77 ^c	$\bar{x}$		186	187	194	
	n		8	46	5	

^afrom present study

^bfrom Martin (1980)

^cfrom McLeod et al. (1978)

(d) Scale Studies

Differences in scale characteristics have been used to identify races of various salmon species. The methods used include comparing the number of circuli in each growth zone, and the distance to each annulus (Henry 1961). Vernon (1957) successfully employed differences in scale characteristics to separate kokanee from the West, North, and South arms of Kootenay Lake.

Two distinct races of kokanee were identified from scales used in age determinations. The primary character used in this differentiation was the number of circuli to the first annulus, counted on the posterior portion of the scale. The mean number of circuli present on the scales of 20 two-year-old and 20 three-year-old specimens taken from the mainstem Columbia River upstream of Norns Creek was 6.5 (S.D. = 0.69) and 6.9 (S.D. = 1.02), respectively. The range for the former was from five to eight circuli, and for the latter was five to nine circuli. A t-test indicated no significant difference ($p > 0.05$) between the mean number of circuli for age-2 and age-3 Columbia River kokanee. The corresponding mean number of circuli for individuals from Norns Creek was 12.6 (S.D. = 1.24), with a range of 11 to 14 circuli ($n = 9$). Figures 3.8 and 3.9 show scales from kokanee captured in the mainstem Columbia River and in Norns Creek, respectively.

In addition to the difference in the number of circuli formed during the first year of life, the extent of resorption during the final year of life was noted. This technique was useful in identifying the three stocks of Kootenay Lake kokanee (Vernon 1957). Resorption had varied between slight in the South Arm, and extreme in the West Arm; scale resorption was very similar in mature kokanee within each area. Scales from mature Columbia River kokanee, captured upstream of Norns Creek in late August and September 1980, exhibited very little or no resorption. Scales from kokanee in Norns Creek showed moderate to heavy resorption.

(e) Sex Ratio

The male to female (m:f) sex ratio of a sample of 18 mature fish (i.e., they would spawn in the fall) captured in the mainstem Columbia River was 0.38:1. For the nine mature individuals examined from Norns Creek (of which

eight were dead at the time of collection), the m:f ratio was 2:1. Fleck (1975) reported a 1:1 sex ratio for spawners in Meadow Creek, a tributary to Kootenay Lake.

(f) Fecundity

Egg counts were conducted on the ovaries from seven kokanee from the Columbia River mainstem. The mean fecundity was 809 eggs (S.D. = 676.2); the range was from 198 to 1942 eggs. Fecundity was positively correlated with fork length ($r^2 = 0.847$) and with body weight ($r^2 = 0.830$). Fleck and Andrusak (1977) reported a mean fecundity of 815 eggs (range = 441-1317) for kokanee sampled in Redfish Creek in August and September 1975. The mean number of eggs per gram of body weight for kokanee from the Columbia River was 1.60 eggs/g, with a range of 1.02 to 3.47 eggs/g. Vernon (1957) reported that female kokanee from Kootenay Lake produced 3.44 eggs/g in the South Arm, 2.05 eggs/g in the West Arm, and 2.33 eggs/g in the North Arm.

3.3.2 RAINBOW TROUT

Rainbow trout were encountered in the Columbia and Kootenay rivers, and in the tributary streams within the study area (i.e., Champion Creek, Murphy Creek, China Creek, and Blueberry Creek). Rainbow trout resident in the tributaries were stunted in growth (i.e., mature males ($n = 5$) ranged in length between 87 and 143 mm). They likely do not contribute significantly to the rainbow trout sports fishery in the area; however, they may have an impact on the sports fishery by feeding on eggs and competing for suitable rearing areas in the tributaries.

The majority of angling effort in the study area is directed toward rainbow trout in the mainstem Columbia River (B.C. Fish and Wildlife Branch 1981). Local anglers reported that the average size of rainbow trout captured in recent years has decreased; however, the catch has not declined noticeably (R. Horney, pers. comm.). The average weight of angled rainbow trout, as documented in the creel survey, was near 1 kg (B.C. Fish and Wildlife Branch 1981).



Figure 3.8. Scale sample from a kokanee captured on 8 May 1980 in the mainstem Columbia River; eight circuli were counted before the first annulus.

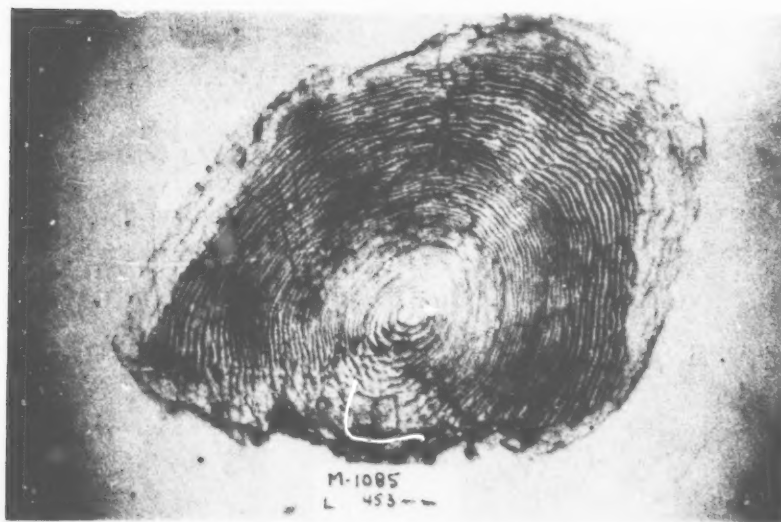


Figure 3.9. Scale sample from a kokanee captured on 2 September 1980 in Norns Creek; 13 circuli were counted before the first annulus.

The following discussion deals primarily with river resident rainbow trout.

3.3.2.1 Abundance and Distribution

In the mainstem Columbia River within the study area, rainbow trout are the most abundant resident salmonid. Although this species contributed only 0.1% to the total number of fish captured or observed during the study, it is evident that they are considerably more abundant than this indicates (i.e., due to the inability to effectively sample their preferred riverine habitat). Gill net CUE for rainbow trout ranged from 0.2 to 3.1 fish/100 m²/24 h (Table 3.12). Night electrofishing CUE ranged from 0 to 4.4 fish/km (Table 3.10). The B.C. Fish and Wildlife Branch (1981) reported that over the duration of their creel survey, the rainbow trout catch per unit effort averaged 0.18 fish/rod hour, which they noted is high for a rainbow trout fishery in a large river.

Capture data from the mainstem Columbia River indicate that adult rainbow trout were most prevalent between Castlegar and the Hugh Keenleyside Dam. Electrofishing of this reach, which is characterized by a slow-flowing channel, yielded greater numbers of juvenile and adult rainbow trout per kilometre than electrofishing in fast water reaches of the study area (Tables 3.19 and 3.20). A similar pattern was evident in the creel survey results of the B.C. Fish and Wildlife Branch (1981). The greater abundance of rainbow trout in the slow-moving reach upstream of Castlegar may be due to higher food availability. Primary food items such as forage fish and mysids were most prevalent in this habitat.

Discontinuous areas of upwelling, backeddies, and slow-moving water downstream of Castlegar also provide suitable habitat for rainbow trout juveniles and adults. Many of these isolated areas are favoured fishing spots for local residents (e.g., Waterloo Eddy at Km 39.2, Slough Eddy at Km 25.5). Frequent observations of rainbow trout surface feeding in such areas were made by the field crews.

Table 3.19. Electrofishing catch and CUE (No. fish/km) for all slow flowing sections (ES-17 to 21 and ES-26 to 30) of the mainstem Columbia River, 1980 and 1981.

Period	Distance (km)	Number ^a and CUE															Total Fish CUE
		YW	K	RT	BT	DV	MW	Suckers ^b	LNS	LSS	BLS	NSF	LING	SCULPIN ^b PM	RSS	Carp	
Spring 29 April-11 May	8.8		93	25	1	39			13	8		3	6	5	211		404
			10.6	2.8	0.1	4.4			1.5	0.9		0.3	0.7	0.6	24.0		45.9
Summer 11-18 July	18.7		567	39		1570		1022	69	46		22	34	349	1617	23028	28363
			30.3	2.1		84.0		54.6	3.7	2.5		1.2	1.8	18.7	86.5	1231.4	1516.7
Fall 26 Aug.-11 Sept.	18.0		3	38	3	4	2204	4130	32	37	1	17	75	686	12	42531	49774
			0.2	2.1	0.2	0.2	122.4	229.4	1.8	2.1	<0.1	0.9	4.2	38.1	0.7	2362.8	2765.2
Winter 29 Jan.-6 Feb.	6.2		1		2	21		27	3	1		1		7	476		539
			0.2		0.3	3.4		4.3	0.5	0.2		0.2		1.1	76.8		86.9
Total CUE	51.7	4	698	67	7	3834		5179	117	92	1	43	115	1042	1634	66246	79080
		<0.1	11.5	1.3	0.1	74.2		100.2	2.3	1.8	<0.1	0.8	2.2	20.2	31.6	1281.4	1529.6

^aTotal fish encountered (captured and observed).

^bObserved, not identified to species.

Table 3.20. Electrofishing catch and CUE (No. fish/km) for all fast flowing sections (ES-1 to 16, and ES-22 to 25) of the mainstem Columbia River, 1980 and 1981.

Period	Effort (km)	Number ^a and CUE																Total Fish CUE
		YM	K	KI	BI	UV	MW	Suckers ^b	LNS	LSS	BLS	NSF	LING	Sculpin ^b	PM	RSS	CARP	
Spring 29 April-11 May	5.8		2	4		2	17		4	17		5		2				53
			0.14	0.7		0.1	2.9		0.7	2.9		0.9		0.3				9.1
Summer 11-18 July	14.8		1	12		2	99	86		44	6	14		5	12	96		377
			0.1	0.8		0.1	6.7	5.8		3.0	0.4	0.9		0.3	0.8	6.5		25.5
Fall 26 Aug.-11 Sept.	22.1	3	6	8	1		310	419		124	4	8	8	151	1	83		1126
		0.1	0.3	0.4	0.1		14.0	18.9		5.6	0.2	0.4	0.4	6.8	0.1	3.8		50.9
Winter 29 Jan.-6 Feb.	2.5					2	45	20		2								69
						0.8	18.0	8.0		0.8								27.6
Total CUE	43.8	3	9	24	1	6	471	525	4	187	10	27	8	158	13	179	0	1625
	0.1	0.2	0.5	0.1	0.1	0.1	10.7	12.0	0.1	4.1	0.2	0.6	0.2	3.6	0.3	4.1		37.1

^aTotal fish encountered (captured and observed).

^bObserved, not identified to species.

Electrofishing catch data (Figure 3.6) and creel survey data (B.C. Fish and Wildlife Branch 1981) showed similar seasonal catch trends. In both cases, capture success was greatest in the spring, with catches declining through the summer and fall. Electrofishing in the river section upstream of Castlegar during the winter sampling period did not capture any rainbow trout. The variations in seasonal catch trends may be due to a number of factors. During the spring, rainbow trout appear to congregate in the upper sections of the river, in the vicinity of their spawning areas (i.e., Norns Creek, Champion Creek, and possibly the mainstem Columbia River upstream of Norns Creek). At this time, they are more susceptible to capture techniques such as angling and electrofishing. Tag return results indicate that there is a general downstream post-spawning migration (with many fish moving out of the study area), which would result in dispersion of the adult fish, making them less susceptible to capture techniques. The absence of rainbow trout in the electrofishing catch in the upper sections of the study area during the winter survey period may have been the result of rainbow trout (and most other species) leaving the upper section of the river for some unknown reason (possibly high dissolved gas concentrations; see Section 3.1.1.1). Alternatively, the rainbow trout may occupy deeper water during the colder winter months, making them less susceptible to capture by electrofishing.

Gill net capture results generally show similar trends to electrofishing results with the exception of low catch rates during summer (Table 3.12). The low catch rate during the summer was in part due to the fouling of the nets by detached filamentous algae and other fibrous materials. In addition, the gill net set at site GN-1 (see Tables B.2 and B.3, Appendix B) on 16 July was a daytime set; no fish were captured although juvenile rainbow trout were seen rising at the surface in the vicinity of the net. Due to the poor capture success of the daytime set at this site during the summer sampling period, the net was set overnight during the fall (1 September). A total of four rainbow trout were captured, giving a high CUE in comparison to the summer sampling period.

3.3.2.2 Movement Patterns

Tag return data indicate that significant spawning-related movements of rainbow trout occur within the study area. Of the 109 adult rainbow trout tagged in the spring of 1981 during the intensive sampling of Norns and Champion creeks, 10 had been recaptured and returned to the B.C. Fish and Wildlife Branch prior to the preparation of this report (Appendix D). Of the 10 fish, six were caught below the proposed Murphy Creek damsite and two were caught within a short distance upstream of the damsite (i.e., near Birchbank). These recaptures indicate that a significant proportion of the rainbow trout that spawn in Norns Creek and Champion Creek migrate downstream to summer feeding areas below the proposed damsite.

3.3.2.3 Spawning

(a) Enumeration of Spawners

A partial enumeration of rainbow trout spawning in the major tributaries was conducted during the 1981 spring period. In Norns Creek, 94 mature rainbow trout were captured by trapping during the monitored portion of the spawning migration (Table C.3, Appendix C); however, since the traps were not operational during a portion of the run, the total number of fish spawning in the creek would be greater. Based on observations of the proportion of tagged fish in the creek, it was estimated that approximately 250 to 350 adult rainbow trout spawned in Norns Creek during the spring of 1981 (Table 3.21).

In Champion Creek, freshet conditions and low water temperatures (i.e., average 3° to 4°C) likely delayed most of the spawning run into the stream until after the 1981 spring survey had concluded. Only seven mature rainbow trout were captured during the trapping period in Champion Creek (Table C.4, Appendix C). An additional eight rainbow trout were observed entering Champion Creek in a 3-hour period on 7 May, the day the trap was being removed. This occurrence may have signified the initial stages of a spawning movement into the creek. By this time, water levels had stabilized and the water temperatures reached 7°C for the first time in 4 weeks. On a subsequent survey on 17 May 1981, eight untagged rainbow trout were

Table 3.21. Rough estimates of the number of adult rainbow trout spawning in Norns Creek, spring 1981. The estimates were derived using Chapman's mark-recapture equation (Ricker 1975).

Date 1981	No. Observed in Creek (C)	No. Tagged Fish Observed (R)	Total No. Tagged Fish in Creek (M) ^a	Estimate of Total No. in Creek
18 April	47	19	33	82 ₋₁₄ (S.D.)
27 April	39	13	82	237 ₋₄₉ (S.D.) ^b
8 May	44	15	92	262 ₋₅₁ (S.D.) ^c

^aThese estimates assume that no tagged fish left the stream during the period the trap was not operating due to high water levels (i.e., 24-25 April and 30 April to 4 May). Although this assumption likely is not true, fewer tagged fish in the stream would decrease the estimated totals, so the estimates provided can be considered conservative estimates.

^bPrior to this survey, three rainbow trout had been processed through the trap oriented to capture fish moving out of the creek.

^cPrior to this survey, a total of 10 rainbow trout had been processed through the trap oriented to capture fish moving out of the creek.

observed in a pool at Km 0.1 of Champion Creek. Due to the delayed timing of the spawning run into Champion Creek in comparison to Norns Creek, it was not possible to obtain an accurate estimate of the spawning population of rainbow trout in Champion Creek. The presence of at least 15 mature rainbow trout in the 1981 spring survey and the abundance of rainbow trout fry in the 1980 fall study period suggest a significant spawning population may be present; however, based on available habitat conditions, the number of migrant trout spawning in Champion Creek is probably less than the number spawning in Norns Creek.

Backpack electrofishing and walking surveys during the spring studies did not indicate the spawning use of Murphy Creek, China Creek, or Blueberry Creek by rainbow trout resident in the Columbia River. The apparent absence of the river residents may be a result of the high water levels exhibited by these creeks during both the 1980 and 1981 spring study periods (i.e., during freshet). Also, the low levels of the Columbia River during the spring of 1981 may have significantly reduced the accessibility of these creeks to river resident fish. Based on the apparent absence of large, mature rainbow trout in these tributaries during the spring surveys, there does not appear to be a major spawning migration from the Columbia River into China Creek, Murphy Creek, or Blueberry Creek. It is possible that the majority of rainbow trout fry noted in these tributaries originate from the stunted stream-resident populations, or from a few Columbia River resident fish that manage to spawn in these tributaries after freshet periods.

On 17 April 1981, approximately 30 large rainbow trout were observed on a gravel bar in the Kootenay River below Brilliant bridge. Spawning behaviour (i.e., digging of redds) was observed, indicating definite spawning use of the area.

Rainbow trout also may spawn in the mainstem Columbia River. Young-of-the-year were captured by beach seining at most sites along the mainstem during the summer survey period (Table C.1, Appendix C). Also, the stomach of a juvenile rainbow trout captured at Km 55.9 on the Columbia River during spring 1981 contained rainbow trout eggs (identified by size and colour), indicating possible spawning use of this section of the river. Local

residents reported capturing several ripe rainbow trout between Km 40 and Km 56.2. Based on these observations, it is likely that spawning occurs in the mainstem; however, the number of rainbow trout spawning in these areas, or the survival of the eggs (i.e., fluctuating water levels would reduce survival) is unknown.

(b) Chronology of Spawning

The chronology of spawning within the study area appears to be dependent on physical factors such as water quality, water levels, and water temperature in the particular tributary. As these factors may vary significantly between various spawning areas (Appendix E), the chronology of the spawning period may similarly vary between areas. For this reason, only the chronology of Norns Creek spawning activity was documented in detail during the 1981 spring study.

Evidence indicates that rainbow trout spawning in Norns Creek in 1981 occurred between early April and late May. The first gravid fish (female and male) were captured on 15 April, the first day the trap was checked (Table 3.22). The first ripe male and female were captured on 16 April and 18 April, respectively. The low numbers of females entering Norns Creek in a ripe condition (i.e., less than 10% were ripe) may indicate that females remain in a gravid state of maturity until immediately prior to actual spawning, at which time they undergo rapid maturation in the warmer creek water. There was no major difference in the number of ripe versus non-ripe males entering Norns Creek over the duration of the study (i.e., 16 ripe males out of 29 total). The first spent male and female rainbow trout in Norns Creek were captured by backpack electrofishing on 18 April.

The movement of rainbow trout into Norns Creek occurred almost entirely in hours of dusk or darkness (i.e., only two rainbow trout were captured in the trap during daytime). During the 1981 spring period, daily water temperature ranged between 3°C and 10°C (Appendix D). Evening water temperatures (i.e., 1800 h) ranged between 6°C and 9°C. Movement into Norns Creek was greatest when evening water temperatures ranged between 6°C and 9°C (Figure 3.10). Although Scott and Crossman (1973) indicate that the

Table 3.22. Daily captures of rainbow trout at the trapping site in Norns Creek, spring 1981.

Date	Gravid		Ripe		Spent		Total	
	Male	Female	Male	Female	Male	Female	Male	Female
April								
15	4	6					4	6
16		4	2				2	4
17	1	5					1	5
18		10	3	2	1	3	4	15 ^a
19		6	2	1			2	7
20	2	9	1	1			3	10
21		7	1	1			1	8
22		5	3				3	5
23	2						2	
26					1	1	1	1
27		1						1
28		1	1				1	1
29		1	2			4	2	5
30	1	1	1	1		1	2	3
May								
1		1						1
6	1						1	
7	1						1	
8	1						1	
Total	13	57	16	6	2	9	31	72

^a includes eight captures by electrofishing within the lower 2.2 km of the creek.

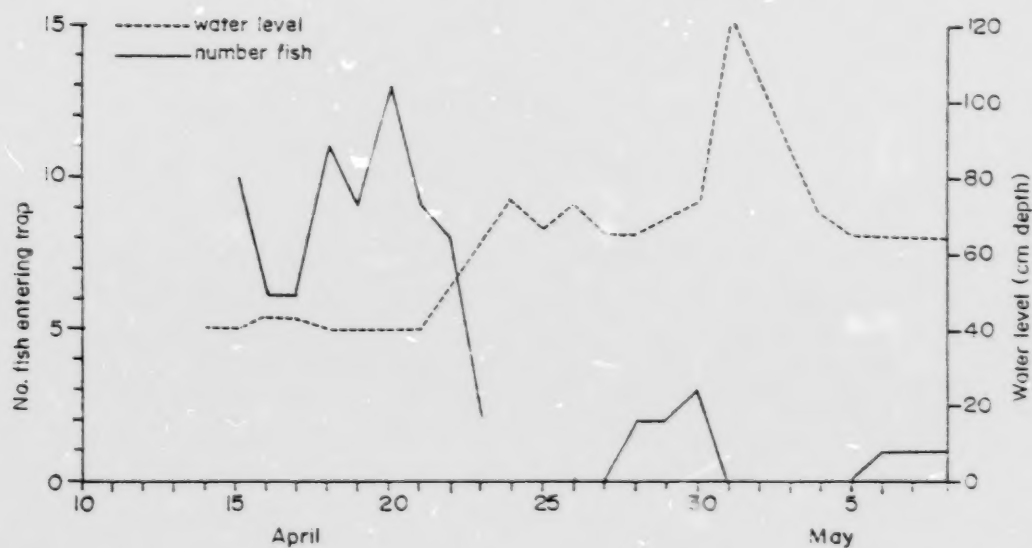
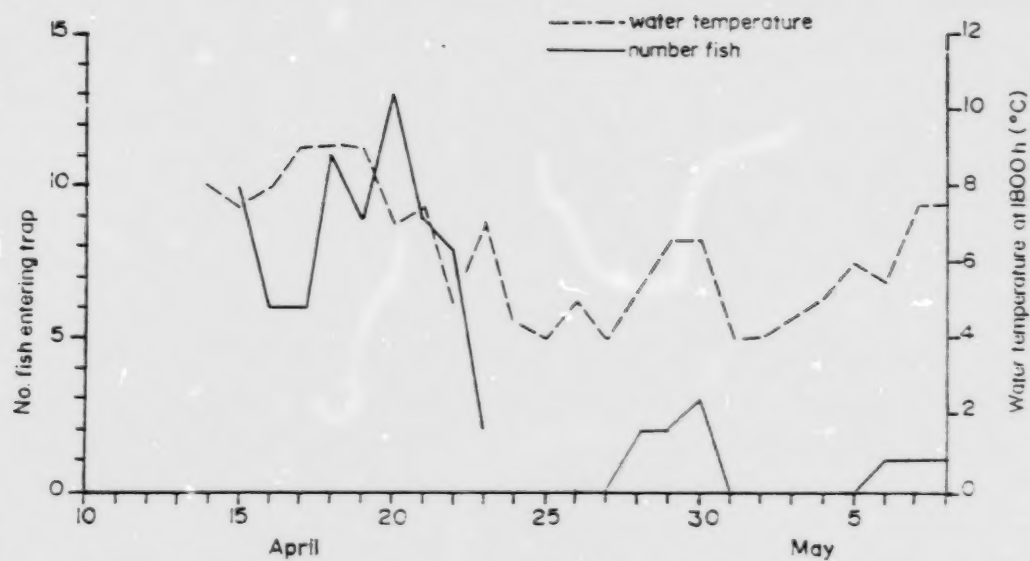


Figure 3.10. Relationship of water temperature and water level to daily number of rainbow trout entering the trap in Norns Creek, spring 1981.

temperature during rainbow trout spawning usually ranges between 10° and 15.5°C, spawning in Norns Creek occurred at temperatures below 10°C.

Ten rainbow trout were captured in the trap oriented to capture downstream migrants; however, freshet conditions necessitated the removal of the fence on two separate occasions; hence, no information was obtained on the length of time rainbow trout spend spawning in Norns Creek.

(c) Habitat Utilization

Mainstem—The capture of ripe rainbow trout in the mainstem Columbia River during the 1980 spring study and the occurrence of rainbow trout eggs in the stomach of a juvenile rainbow trout captured at Km 55.9 suggest that certain areas of the mainstem are utilized for spawning by rainbow trout. The exact locations of such areas are not known.

Kootenay River below the Brilliant Dam—The capture of ripe individuals by local anglers below the Brilliant Dam suggests the spawning utilization of the mainstem Kootenay River by rainbow trout. On 17 April 1981, 20 to 30 large rainbow trout were observed spawning on a gravel shoal in the Kootenay River just downstream of the highway bridge. Spawning occurred over uniformly large gravels and cobbles at a depth of 2 to 5 m.

Tributary Creeks—Norns Creek—Mature rainbow trout were widely distributed through the lower 1.86 km of Norns Creek. Prolific utilization of isolated areas was observed and confirmed by sampling the substrate for eggs. These major use areas are located at Km 1.05 to 1.15 and Km 1.65 to 1.7 (Figure 3.7). Substrate in these areas consisted of uniformly-sized gravels (2 to 7 cm in diameter), surface water velocity ranged from 0.8 to 1.1 m/s, and depths ranged between 20 and 100 cm. These areas generally were adjacent to riffle areas. Other areas where spawning was confirmed include the section from Km 0.38 to 0.50. These areas were characteristically adjacent to major pools (i.e., greater than 1.5 m in depth). Locations where numerous rainbow trout were observed but were not confirmed to be

spawning, include the pool and run section from Km 0.8 to 0.9, and the pool at Km 1.26.

Other Creeks—The low numbers of rainbow trout in combination with adverse flow and turbidity conditions, prohibited documentation of habitat utilization in Champion, Murphy, China, and Blueberry creeks.

3.3.2.4 Rearing

Numerous young-of-the-year and juvenile rainbow trout were captured (using a backpack electrofisher) during the 1980 summer and fall survey periods in the major tributaries (i.e., Norns Creek, Champion Creek, Murphy Creek, China Creek, Blueberry Creek) (Appendix A). The abundance of juvenile rainbow trout indicates the availability of suitable spawning and rearing habitat in these systems. Since most of these tributaries contain resident populations of stunted rainbow trout, many of the juveniles noted were likely progeny of the resident populations.

Young-of-the-year and juvenile rainbow trout also were captured (by beach seining) at most sites along the mainstem Columbia River during the summer period. The number encountered generally was low (Table 3.13), probably due to the ineffectiveness of the beach seine in the clear water, the large substrate size, and the sharp drop-off from shore. Suitable rearing habitat was extensive along the mainstem; however, competition with coarse fish (e.g., redbreast shiner) for food and space, and also predation by such fish, may limit the use of rearing habitat in some areas, especially between Castlegar and the Hugh Keenleyside Dam. Larkin and Smith (1954) indicate that the presence of large redbreast shiner populations can seriously reduce the rearing capacity of a system for trout.

3.3.2.5 Feeding

Crossman and Larkin (1959) noted a wide variety of organisms in the diet of rainbow trout including plankton, larger crustaceans, insects, snails, and leeches. They reported that redbreast shiners were a major food item in trout greater than 20 to 25 cm in length; the winter diet of all sizes of

rainbow trout consisted mainly of bottom fauna. Crossman and Larkin (1959) also indicated that in the absence of redbase shiners (or probably any small forage fish), aquatic invertebrates were the major component of the diet. This is likely true for rainbow trout in the high gradient portion of the Columbia River, where redbase shiners are not abundant. Local anglers report that emerging aquatic insects (e.g., mayflies, stoneflies, caddisflies) are the major food items for rainbow trout in the lower section of the river during the summer and fall (R. Horney, pers. comm.; R. DeBiasio, pers. comm.). At certain times of the year, rainbow trout in the upper section of the Columbia River likely feed on mysids and other zooplankton entering from Arrow Lake through the Hugh Keenleyside Dam. Since most rainbow trout captured during the present study were tagged and released, insufficient numbers of rainbow trout were sacrificed to allow detailed comment on food utilization.

3.3.2.6 Life History

A total of 381 rainbow trout were sampled for life history information during this study; of these, 15.0% ($n = 57$) were captured in the mainstem Columbia River. The remaining samples were collected in tributary streams.

(a) Size Distribution

Columbia River—The fork length of rainbow trout collected from the Columbia River ranged between 24 and 582 mm. Thirty-five percent of the fish captured ranged between 250 and 324 mm in length ($n = 20$). The heaviest rainbow trout collected from the Columbia River weighed 2850 g (fork length = 582 mm).

Norns Creek—Rainbow trout captured in Norns Creek ($n = 166$) ranged between 25 and 625 mm in fork length. Fifty-six percent of the fish from Norns Creek sampled for life history information ranged between 450 and 599 mm in fork length ($n = 93$); these individuals represented an adult migrant population that moved into Norns Creek during the spring to spawn. Young-of-the-year rainbow trout also were abundant, with the 25 to 49 mm size

class contributing 26.5% ($n = 44$) to the total catch sampled. The heaviest rainbow trout captured in this tributary weighed 3000 g (fork length = 625 mm).

Kootenay River—Only one rainbow trout from the Kootenay River was sampled; it was captured in a gill net set near the confluence with the Columbia River on 14 July 1980. It measured 468 mm in length and weighed 1320 g.

Blueberry Creek—The 28 rainbow trout from Blueberry Creek that were measured ranged between 24 and 128 mm in fork length. Thirty-nine percent ($n = 11$) of these individuals ranged between 25 and 49 mm in length.

Champion Creek—Rainbow trout sampled in Champion Creek ($n = 52$) ranged between 30 and 560 mm in length. The larger individuals represented adults that moved into the creek in the spring to spawn. Sixty-nine percent ($n = 36$) of the fish were less than 100 mm in length. The heaviest fish weighed 2080 g (two individuals with fork lengths of 560 mm and 550 mm).

China Creek—The 43 rainbow trout collected in China Creek ranged in length between 23 and 160 mm. Twenty-eight percent ($n = 12$) of these individuals fell within the 75 to 99 mm size class.

Murphy Creek—Rainbow trout sampled in Murphy Creek ($n = 34$) ranged in length between 37 and 128 mm. Thirty-eight percent ($n = 13$) of the fish measured ranged between 50 and 74 mm in length.

(b) Length-Weight Relationships

The length-weight relationship for rainbow trout captured in the mainstem Columbia River is expressed by the following equation:

$$W = (1.03 \times 10^{-5}) \times L^{3.028} \quad (n = 47; r^2 = 0.996)$$

where: W = weight in grams;

- L = fork length in millimetres;
n = sample size; and
 r^2 = the coefficient of determination

(c) Age-Length Relationships

Age-length data for rainbow trout from the study area are difficult to interpret due to small sample sizes for some age classes and due to the presence of both slow-growing resident trout populations and migrant populations. Also, rainbow trout are difficult to age from scales, so possible aging errors in conjunction with small sample sizes further complicates detailed comparison of growth rates. In general, however, rainbow trout resident in the mainstem Columbia River (including the fish that spawn in Norns Creek and Champion Creek) attain a very large size (e.g., up to 535 mm in length at age 5). The rainbow trout that remain in the tributaries for more than 1 year appear to grow slowly, attaining sizes that are substantially less than those attained by rainbow trout in the Lardeau River, McGregor River, or the Parsnip River (Table 3.23). Growth rates in most tributaries also were less than growth rates in Brenot Creek (a tributary to the Peace River), which also supports a slow-growing resident population.

(d) Age-Maturity

The youngest rainbow trout spawners captured moving into Norns Creek and Champion Creek during the spring of 1981 were 4-year-olds; however, the majority of the spawners were 5 to 7 years old. In the tributary streams, mature individuals (aged as 2-year-olds and 3-year-olds) were noted. These fish were assumed to be slow-growing resident fish.

(e) Sex Ratio

The male/female sex ratio for rainbow trout spawning in Norns Creek during the spring of 1981 was 0.43:1 ($n = 103$). The reason for the low numbers of males in the spawning run was not clear, but may be related to differences in susceptibility to capture by angling between the two sexes;

Table 3.23. Comparison of age-length data for rainbow trout from the Columbia River and its tributaries within the study area, and various locations within British Columbia. $\bar{x}$ = mean fork length (mm) and n = sample size.

Location	Age									
	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+
Columbia River ^a	$\bar{x}$ 27	61	95	204	268	308	430	382	462	516
	n 4	1	1	7	9	12	2	2	5	3
Blueberry Creek ^a	$\bar{x}$ 38	62	105							
	n 9	12	3							
Champion Creek ^a	$\bar{x}$ 42	63	99	143		535	488	543		
	n 13	14	7	1		1	3	3		
China Creek ^a	$\bar{x}$ 32	67	97	143						
	n 11	5	13	1						
Murphy Creek ^a	$\bar{x}$ 49	59	102	124						
	n 5	8	8	3						
Norns Creek ^a	$\bar{x}$ 29	76	79	165	399	477	516	558	581	
	n 43	3	12	2	1	21	36	25	3	
Lardeau River ^b (spring/summer)	$\bar{x}$ 40	102	136							
McGregor River ^c	$\bar{x}$ 261	53	19							
	n 20	120	176	259	294	317	344		412	1
	$\bar{x}$ 8	4	21	42	33	8	2			
Parsnip River ^c	$\bar{x}$ 50	125	192	243	288	329	349		397	
	n 6	15	18	28	23	10	4		1	
Brenot Creek (tributary to Peace River) ^d	$\bar{x}$ 89	89	127	182	200	232				
	n 10	10	9	2	3	2				

^a Present study

^b Irvine (1978)

^c McLeod et al. (1978)

^d Renewable Resources Consulting Services Ltd. (1978)

angling pressure was heavy near the confluence of Norns Creek during the early portion of the run.

3.3.3 DOLLY VARDEN

Dolly Varden are the object of an important sport fishery in the Columbia River, being second only to rainbow trout in terms of angling appeal (B.C. Fish and Wildlife Branch 1981).

3.3.3.1 Abundance and Distribution

Dolly Varden are scarce in the Columbia River, contributing less than 0.1% to the total number of fish captured or observed during this study (Table 3.9). Low angler success rates (CUE range 0.0 to 0.03 fish/rod h) for Dolly Varden provide a similar indication of low abundance (B.C. Fish and Wildlife Branch 1981). Local fishermen suggest that the large effort expended for Dolly Varden is directed towards large-sized individuals (up to 12 kg), probably remnants of a former riverine population which existed prior to the construction of the Hugh Keenleyside Dam. Dolly Varden captured during the present study ranged in size from 420 to 3220 g. The presence of the smaller and younger fish (3 to 7 years) suggests that the population is reproducing within the study area, or else there is recruitment of juveniles into the area from Arrow Lakes or Lake Roosevelt.

Electrofishing and gillnetting results indicate that Dolly Varden are most abundant in the farthest upstream section (i.e., near the Hugh Keenleyside Dam) of the Columbia River. This distribution pattern is likely responsible for the extensive angling effort directed toward Dolly Varden in the upper mainstem (B.C. Fish and Wildlife Branch 1981). The abundance of small forage fish in this area increases its attractiveness as feeding habitat for Dolly Varden.

Local fishermen report that Dolly Varden were present throughout the study area in previous years (R. Horney, pers. comm.). A single Dolly Varden captured in a gill net near Trail was the only evidence of the presence of this species downstream of Castlegar; however, sampling effort and efficiency was low throughout this section.

3.3.3.2 Movement Patterns

Little is known concerning the movement pattern of Dolly Varden within the study area. One large, tagged specimen was released at Km 54.1 on 3 May 1980 and was recaptured on 14 July 1980 at Km 54.9. It was subsequently recaptured on 1 March 1981 near the same location by an angler. This suggests that at least a portion of the population is resident in the area.

The movement of Dolly Varden into the study area from Arrow Lakes has been documented by the B.C. Fish and Wildlife Branch from the recapture below the Hugh Keenleyside Dam of Dolly Varden that were tagged at the Revelstoke project site (H. Andrusak, pers. comm.). These represent a net downstream movement of over 233 km.

3.3.3.3 Spawning and Rearing

No information is available regarding Dolly Varden spawning in the study area. In Mackenzie Creek, a tributary to Upper Arrow Lake, spawning occurs from mid-September to late October (McPhail and Murray 1979). Suitable spawning areas in that system were located in low gradient reaches with large gravel substrate; water temperatures were near 9°C at the time of spawning. Within the present study area, only the lower 2 km of Norns Creek, the lower 1.8 km of Champion Creek (1980 water levels in this stream were too low to allow upstream migration), and possibly isolated areas of the mainstem Columbia River provide potentially suitable spawning habitat for Dolly Varden. Competition for suitable spawning areas between Dolly Varden and kokanee may occur if the spawning period of these two species overlaps. Spawning of Dolly Varden in Norns Creek in previous years has been reported, although the timing and extent is not known (H. Andrusak, pers. comm.; F. Salekin, pers. comm.). There was no evidence of Dolly Varden spawning in any of the streams surveyed in 1980; however, an upstream migration into Norns Creek may have occurred after the fall survey was terminated.

McPhail and Murray (1979) suggest that Dolly Varden may spend the first 1 or 2 years of their lives in the creeks in which they were spawned, or they may migrate out of the stream as fry. They also note that suitable

rearing habitat for young-of-the-year Dolly Varden consists of low velocity backwaters, whereas older juveniles frequent pools. These habitats occur in both Norns Creek and the mainstem Columbia River but sampling of these types of habitat gave no indication of their utilization by juveniles of this species.

3.3.3.4 Feeding

The diet of Dolly Varden consists of a wide variety of food organisms. Stream resident juveniles generally feed on adult and immature insects, snails, and leeches in summer periods; salmon eggs also are consumed, if available, in the fall (Scott and Crossman 1973). Adult Dolly Varden are mainly piscivorous. The stomachs of three Dolly Varden, captured at the base of the Hugh Keenleyside Dam, contained small kokanee; stomach fullness ranged from 50% to 100%.

3.3.3.5 Life History

A total of 12 Dolly Varden captured in the Columbia River were sampled for life history information during this study; no Dolly Varden were captured in any of the tributaries within the study area.

(a) Size Distribution

The Dolly Varden captured ranged in fork length from 338 to 604 mm, with the mean length being 464 mm ($n = 12$; S.D. = 85.7). The heaviest individual weighed 3220 g (fork length = 604 mm).

(b) Length-Weight Relationships

Due to the small sample size, the length-weight relationship was not calculated for this species.

(c) Age-Length Relationships

Since all but two of the Dolly Varden captured were tagged and released, only scales were taken for age determination. Scales are not the

preferred material for aging Dolly Varden (i.e., otoliths generally are considered to be more accurate); hence, the ages as presented must be used with caution. The Dolly Varden sampled from the Columbia River ranged in age between 3+ and 7+. The age-length relationships were as follows:

	Age			
	3+	4+	5+	7+
mean fork length (mm)	368	441	522	604
sample size	3	4	4	1
standard deviation	27.5	32.6	66.5	-

These length-at-age data compare relatively closely to those presented by McPhail and Murray (1979) for Dolly Varden in Upper Arrow Lake.

3.3.4 MOUNTAIN WHITEFISH

In recent years the mountain whitefish has gained popularity as a game fish in many parts of British Columbia. In the Columbia River, this fish has not been significantly exploited, probably due to the presence of other highly valued salmonid species in the area.

3.3.4.1 Abundance and Distribution

Mountain whitefish were common throughout the Columbia River. They composed 4.7% of the total catch collected during the study (Table 3.9). The length-frequency distribution of mountain whitefish indicated the presence of size-related differences in habitat selection. Adult mountain whitefish, generally greater than 300 mm in length, composed 70% to 90% of the mountain whitefish captures from run or riffle habitats (e.g., electrofishing sections 1 to 16, 23 to 25) in the downstream reaches of the study area. The preferred habitat for adults was small, localized backeddies within riffle sections. Juvenile mountain whitefish, ranging from 175 to 300 mm in length, contributed more than 95% to the catch of mountain whitefish in electrofishing sections 17 to 21 and 26 to 30. These sample sections were located in a comparatively wide, deep, and slow-flowing portion of the Columbia River.

Davies and Thompson (1976) suggest that segregation of pre-adult mountain whitefish from adult age classes (i.e., opposite migrations in the Sheep River, Alberta) may be a behavioural response to avoid predation and/or competition.

Seasonal changes in the abundance of mountain whitefish in slow water habitat (i.e., juveniles) and in fast water habitat (i.e., adults) are apparent (Tables 3.19 and 3.20). The abundance of adults within the samples increased from spring through fall, and reached a maximum in the winter. Juveniles were abundant in the slow-moving reaches above the Castlegar ferry in summer and fall (1980) and spring (1981) (Figure 3.6). Maximum abundance was reached in the fall study period. Reasons for the seasonal changes in abundance of adults and juveniles were not evident.

3.3.4.2 Movement Patterns

Upstream movements of young-of-the-year and juvenile mountain whitefish are suggested by the presence of these age classes above Castlegar, a primarily low velocity reach with limited suitable spawning habitat. In the Sheep River, Alberta, Davies and Thompson (1976) documented post-emergence downstream drift of fry to suitable holding areas with subsequent upstream movements by young-of-the-year and 1-year-olds in late fall to overwintering areas. The increasing abundance of juveniles during summer and fall in the upper sections of the Columbia River could indicate similar movements to overwintering habitat.

The increasing abundance of adult mountain whitefish in the catch during the fall and winter suggests movement into possible feeding and/or spawning areas. The extent of these movements could not be determined due to a lack of tag-recapture data. Adult mountain whitefish in the Sheep River, Alberta, exhibited complex movement patterns including spring feeding, pre-spawning, spawning, and overwintering movements (Davies and Thompson 1976).

3.3.4.3 Spawning and Rearing

Mountain whitefish spawning in the Columbia River occurs in mid-winter. During the winter survey (27 January to 10 February), 32 of 34 adult mountain whitefish captured were either ripe or spent, and were captured in run or riffle areas. Substrates consisted of mainly cobble and boulder. Water temperatures were 3° to 4°C during the period. Davies and Thompson (1976) reported that mountain whitefish in the Sheep River spawned in early October, over a temperature range of 0° to 8°C.

Electrofishing was not conducted in the mainstem downstream of Castlegar during the winter period; as a result, the extent of use of this section of the Columbia River for mountain whitefish spawning is unknown. Frequent riffles and runs with suitable velocity and substrate conditions for spawning occur within the reach. Local residents have reported whitefish spawning activity in riffle areas near Castlegar and Trail.

The presence of large numbers of young-of-the-year mountain whitefish in the study area suggests that spawning use of the mainstem Columbia River is substantial. The presence of a passive downstream migration of large numbers of mountain whitefish fry in Norns Creek during the spring of 1981 also indicates spawning use of this tributary. Local residents report having seen mountain whitefish in Norns Creek during previous winters (B. Salekin, pers. comm.).

Night electrofishing in low velocity habitat upstream of Castlegar indicated that young-of-the-year and subadult mountain whitefish were abundant. Differences in abundance between the two banks were evident and probably due to uneven distribution of suitable rearing areas. These results indicate that the upper reaches of the study area, which were characterized by comparatively low gradient and extensive shallow areas, provide good to excellent rearing habitat for mountain whitefish. There was no evidence that any tributaries were utilized as rearing habitat.

3.3.4.4 Feeding

Examination of the stomach contents of 24 adult and juvenile mountain whitefish indicated that their diet was based on a wide variety of food

organisms, including terrestrial and benthic invertebrates and fish eggs. Caddisfly larvae were the most prevalent food item, contributing 30% to the total volume of food examined. Mayfly nymphs and midge larvae also were important food items. A single adult mountain whitefish captured during May 1980 contained unidentifiable eggs. The average fullness of all stomachs examined was 39% by volume; three stomachs (12.5%) were empty or contained only trace amounts of partially digested matter.

3.3.4.5 Life History

A total of 261 mountain whitefish from the mainstem Columbia River were sampled for life history information. An additional seven specimens were sampled from the other regions in the study area (six from Norns Creek and one from the Kootenay River); however, they have not been included in the following discussion.

(a) Size Distribution

The mountain whitefish sampled from the mainstem Columbia River ranged in length from 52 to 497 mm. The predominant size class was the 100 to 124 mm class which contained 13.0% ($n = 34$) of the individuals; however, the 125 to 149 mm (11.9%) and the 150 to 174 mm (10.3%) classes were nearly as well represented in the catch. No major sex-related differences in size were noted.

(b) Length-Weight Relationships

The length-weight relationship for mountain whitefish captured in the mainstem Columbia River was as follows:

$$W = (3.52 \times 10^{-6}) \times L^{3.219} \quad (n = 243; r^2 = 0.974)$$

where: W = weight in grams;
 L = fork length in millimetres;
 n = sample size; and
 r^2 = the coefficient of determination.

(c) Age-Length Relationships

Mountain whitefish in the Columbia River are larger at a given age than are individuals from a number of other rivers in British Columbia (Table 3.24). The fast growth rate is likely a reflection of a long growing season (i.e., no ice cover in winter) and abundant food supply in the Columbia River. Mysids and other zooplankton entering the river from Arrow Lake undoubtedly contribute significantly to the food source.

(d) Age-Maturity

Age-maturity data indicate that a portion of the population spawn at age 3+ (i.e., four out of five were mature). All age 4+ and older (n = 24) were mature.

(e) Sex Ratio

Of the 43 mountain whitefish for which sex was determined, the male:female ratio was 0.72:1. No explanation for the lower number of males in the sampled population was evident.

(f) Fecundity

Estimates were made of the numbers of eggs in the ovaries of six mountain whitefish from the Columbia River (Table 3.25). The mean fecundity was 7160 eggs (n = 6; S.D. = 904.5); the range was 6167 to 8552 eggs. The mean number of eggs per gram of body weight was 11.8 (range = 8.6-12.9). This value was similar to that reported by Thompson (1974) for mountain whitefish in the Sheep River, Alberta (11.6 eggs/g) and slightly higher than the 10.0 eggs/g of body weight reported by O'Neil et al. (1981) for mountain whitefish from the Liard River, N.W.T.

3.3.5 BURBOT

Burbot, apparently, are common in the Columbia River within the study area. Limited angling effort is directed to the capture of this species during the summer months within the study area; however, during the March-April

Table 3.24. Comparison of age-length data for mountain whitefish from the Columbia River (1980 and 1981) and various locations within British Columbia. $\bar{x}$ = mean fork length (mm) and n = sample size.

Location	Age											
	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
A. Columbia River ^a	$\bar{x}$ 52 n 2	133 91	214 56	293 23	333 21	347 23	370 10	376 5	399 3	438 1	482 1	497 1
B. Kootenay River near Canal Flats ^b	$\bar{x}$ 57 n 14	119 111	161 40	194 83								
C. Liard River ^c	$\bar{x}$ 52 n 4	110 5	168 6	227 8	278 11	314 13	336 9	354 8	394 5	421 4	426 5	440 3
D. McGregor River System ^d	$\bar{x}$ n	96 16	148 33	181 34	210 43	229 26	245 47	269 17	284 10	309 8	312 2	
E. Parsnip River System ^d	$\bar{x}$ n	123 9	168 19	204 8	247 18	260 18	293 4	260 5	338 2	312 3		

^a From present study

^b From Ash and Hyatt (1979).

^c From O'Neil et al. (1981)

^d From McLeod et al. (1978)

Note: older age classes were not analyzed in this study.

Table 3.25. Fecundity estimates for mountain whitefish from the Columbia River. Number of eggs was determined by volumetric displacement.

Sample Number	Fork Length (mm)	Weight (g)	Fecundity Estimates
1053	344	560	6786
1067	346	570	7138
1068	352	620	7875
1069	438	1000	8552
1073	309	500	6167
1115	328	500	6442

period, a considerable amount of burbot angling occurs near the base of the Hugh Keenleyside Dam (B.C. Fish and Wildlife Branch 1981; H. Andrusak, pers. comm.).

3.3.5.1 Abundance and Distribution

Burbot contributed 0.1% to the total catch by all sample methods (Table 3.9). The true abundance of this species in the study area, however, likely is underestimated by all capture methods with the possible exception of set lines. All but one of the burbot were captured by night electrofishing (Table 3.10) or by set lines in the low gradient reaches of the Columbia River upstream of Castlegar. The absence of this species from samples from the higher gradient reaches downstream of Castlegar likely reflects the differing sampling methodology (e.g., day electrofishing versus night electrofishing) and lower sampling effort, rather than their actual absence from this area. Beak (1980) reported that an abundance of burbot was documented by divers in the vicinity of the B.C. Timber Ltd. mill on the upper section of the Columbia River.

3.3.5.2 Movement Patterns

Burbot in the Sogozha River, U.S.S.R., generally occupied the deepest parts of the river channel, migrating into shallower water in summer periods after dusk (Malinin 1971). In the present study the larger catches of burbot recorded during night electrofishing in shallow, inshore areas in the summer and fall survey periods suggests a similar diurnal movement in the Columbia River. The absence of this species from catches in the winter period may reflect the probable high dissolved gas concentrations resulting from winter water releases which would force the fish to move to deeper waters or possibly out of the area. The increased abundance of this species below the Hugh Keenleyside Dam in the March-April period (B.C. Fish and Wildlife Branch 1981) is thought to represent spawning movements into the area. Spillway releases, which produce high total dissolved gas concentrations (see Section 3.1.1.1), generally are discontinued during this period (i.e., discharge through ports only).

3.3.5.3 Spawning and Rearing

Burbot spawn in late winter in shallow waters over sand or gravel substrates (Scott and Crossman 1973). No direct evidence of burbot spawning activity was obtained in the winter survey; however, the presence of suitable spawning habitat in the upper sections of the Columbia River and the reported abundance of burbot in this area during March (B.C. Fish and Wildlife Branch 1981) indicates spawning likely occurs in this area. Rearing use of the study area by juvenile burbot appears limited. Young-of-the-year and yearling burbot were absent from catches in the study area, although the limited sampling conducted in the mainstem Columbia River below Castlegar may have missed juveniles rearing in this area.

3.3.5.4 Feeding

Burbot stomach contents were not examined in the present study. Scott and Crossman (1973) report that the diet of young burbot consists mainly of aquatic insect larvae, crustaceans, and especially *Mysis relicta*. The abundance of mysids in the upper sections of the Columbia River suggests suitable feeding habitat for young-of-the-year and juvenile burbot. The diet of adult burbot consists of a wide variety of fishes. The summer diet of burbot in some areas can consist exclusively of mysids (Clemens 1951).

3.3.5.5 Life History

A total of 28 burbot from the Columbia River were sampled for life history information; however, since most of these individuals were tagged and released, none of the burbot were aged (i.e., otoliths must be used for aging) and no sex-maturity data were obtained.

The burbot sampled ranged between 430 and 656 mm in total length. The predominant size class was the 475 to 499 mm class which contained 43% ($n = 12$) of the burbot sampled. The weights of the burbot ranged between 510 and 1460 g.

Due to the relatively small range in sizes of the burbot sampled for life history information, a length-weight relationship has not been calculated.

3.4 MINOR SPORT SPECIES

3.4.1 WHITE STURGEON

White sturgeon is the largest freshwater fish in Canada, and individuals can live to be over 100 years old. They prefer riverine habitats rather than lakes (Scott and Crossman 1973; Haynes et al. 1978). The sport fishery for sturgeon within the study area has increased substantially over the last few years. Seven permits were issued for the Trail area in 1974; 61 permits were issued in 1980 (B.C. Fish and Wildlife Branch, unpublished data). Length and weight records for a sample of sturgeon caught in 1973 and 1980 are presented in Table 3.26.

No sturgeon were captured during the present study, a likely consequence of the inability to sample their preferred habitat with the sampling methods utilized. The annual angler catch of sturgeon in the study area is estimated to be six fish per year (B.C. Fish and Wildlife Branch 1981); however, the results of a tag and release program recently undertaken by the Fish and Wildlife Branch suggest a much larger population may be present. Ninety-four sturgeon were captured in 4 days of fishing downstream of Trail (B.C. Fish and Wildlife Branch 1981). Only three of the 74 tagged and released sturgeon were recaptured during their study.

3.4.1.1 Abundance and Distribution

White sturgeon are restricted to Pacific drainages; in the Columbia River they have been documented upstream to above Revelstoke, B.C. (Scott and Crossman 1973). Within the study area, sturgeon are caught primarily in the Columbia River between the Castlegar ferry and the Hugh Keenleyside Dam, and in the Kootenay River below the Brilliant Dam (B.C. Fish and Wildlife Branch, unpublished data; H. Andrusak, pers. comm.). The other major area that supports sturgeon fishing in the Columbia River within British Columbia is situated between the confluence of the Pend Oreille River and the International Boundary (P. Scott, pers. comm.). The relative abundance of white sturgeon in the present study area is difficult to assess; however, recent information indicates that they may be considerably more

Table 3.26. Length and weight data for individual white sturgeon captured by anglers in the mainstem Columbia River (between Hugh Keenleyside Dam and the International Boundary) and the Kootenay River (between the Brilliant Dam and the Columbia confluence), for 1973 and 1980 (B.C. Fish and Wildlife Branch, unpubl. data).

Date	Location	Length (cm)	Weight (kg)
1973			
July	Kootenay R. below Hwy. #3 bridge	-	72.6
July	Kootenay R. below Hwy. #3 bridge	-	90.8
July	Kootenay R. below Hwy. #3 bridge	224	-
July	Kootenay R. below Hwy. #3 bridge	-	38.6
August	Kootenay R. - east channel	-	22.7
1980			
February	Columbia R. below Hugh Keenleyside Dam	114	25.5
28 May	Columbia R. just upstream of the U.S. border	124	31.8
18 August	Columbia R. between Waneta and the U.S. border	<u>122</u>	<u>22.7</u>
Mean		146	43.5

abundant in the river than the present angler catch indicates (B.C. Fish and Wildlife Branch 1981).

3.4.1.2 Movement Patterns

Anadromous forms of white sturgeon undertake long spawning migrations from the Pacific Ocean to spawning areas in the coastal rivers (Scott and Crossman 1973). Fresh water populations apparently move upstream in the fall and early winter and move downstream in late winter and spring. Haynes et al. (1978) reported that white sturgeon in the Columbia River, between Priest Rapids and McNary Reservoir (Washington), moved less than 0.2 km from November to May; the majority of movement occurred from mid-June to October. They also determined that larger sturgeon moved upstream in summer and fall, while the smaller individuals moved downstream during this period. Haugen (1969) documented lake sturgeon, a close relative of the white sturgeon, moving distances of up to 60 km in the South Saskatchewan River (Alberta). On the basis of these findings, defined movements of white sturgeon within the study area can be expected although the nature and timing of these movements are presently unknown.

3.4.1.3 Spawning and Rearing

White sturgeon reportedly spawn between May and June, usually over rocky bottoms in areas with swift currents (Scott and Crossman 1973). Zakharyan (1972) documented three species of sturgeon (i.e., Russian, stellate, and spiny) spawning from April to June in the fast water below hydroelectric dams in the Kura and Araks rivers in the U.S.S.R. Miller (1972) recorded white sturgeon spawning in February to May in the Sacramento and San Joaquin rivers (California), with larvae emerging in March to May. H. Andrusak (pers. comm.) suggests that sturgeon may spawn in the Kootenay River just below the Brilliant Dam. Although actual spawning areas have not been documented, the presence of young sturgeon in the Columbia River indicates that this species is reproducing in this river system (H. Andrusak, pers. comm.).

There are considerable differences in the age-at-first-maturity between sexes. In the Fraser River, white sturgeon males first spawn between 11 and

22 years of age, while females do not mature until 26 to 34 years of age. Spawning does not occur every year; rather, it is reported to occur at intervals of 4 to 11 years (Scott and Crossman 1973).

The delayed maturation period and extended interval between consecutive spawning periods would increase the susceptibility of this species to major habitat disturbances (e.g., flooding of spawning grounds). This is particularly true in a closed system such as the Columbia River between the Hugh Keenleyside Dam and Lake Roosevelt.

3.4.1.4 Feeding

White sturgeon are bottom feeders, with the smaller individuals primarily feeding on chironomids (Scott and Crossman 1973). Larger sturgeon have a more varied diet including molluscs, aquatic insects, mysids, crayfish, and small fishes (Scott and Crossman 1973). Although no data are available describing white sturgeon feeding habits within the present study area, there likely is ample food available.

3.4.2 WALLEYE

Walleye is a prized sport fish of considerable economic value throughout most of its range (Bidgood 1973, 1978; Scott and Crossman 1973; Colby et al. 1979). Walleye are a recent addition to the species assemblage in the study area; they presumably originated from Lake Roosevelt. Walleye apparently were not deliberately stocked in Lake Roosevelt; they were either introduced accidentally (e.g., as baitfish), or entered from the Flathead River system via the Clark Fork and Pend Oreille rivers (tributary to the Columbia River) (R. Duff, pers. comm.).

3.4.2.1 Abundance and Distribution

During the present study, only four walleye were captured (Table 3.9), all between the Castlegar ferry and the Hugh Keenleyside Dam; three others were observed (one near the C.P.R. bridge at Castlegar, and the two others above the Castlegar ferry). Walleye reportedly have been captured by angling from the Kootenay River below the Brilliant Dam (B. Salekin, pers.

comm.), and from the confluence of the Pend Oreille River and the Columbia River (Stewart 1980). Local residents within the study area have reported the capture of walleye from the Arrow Lakes (above the Hugh Keenleyside Dam), but the B.C. Fish and Wildlife Branch has not yet confirmed the presence of this species in the reservoir (W. Campbell, pers. comm.). Any walleye present in the Arrow Lakes presumably would have entered the system through the boat lock at the Hugh Keenleyside Dam.

3.4.2.2 Movement

Walleye have been reported to undertake extensive seasonal movements (Wolfert 1963; Machniak 1975; Falk et al. 1980). The reported long distances travelled by walleye (i.e., up to 380 km cited by Wolfert 1963) suggests that the distance between the suspected source of origin in Lake Roosevelt and the Hugh Keenleyside Dam (approximately 90 km) is well within the seasonal migration capabilities of this species. The exact stimulus or purpose for movements is presently unknown, but may be related to spawning or summer feeding activities.

Walleye also exhibit diurnal movements, remaining under cover or in deep waters during the day and moving into shallower areas to feed at dusk (Eschmeyer 1952; Osterberg 1978; Colby et al. 1979). These movements likely account for the majority of walleye being captured in the present study during night electrofishing surveys in shallow, inshore areas (Table 3.10).

3.4.2.3 Spawning

Walleye have been recorded to spawn in rivers and lakes over a wide variety of substrates (e.g., sand, gravels, boulders, logs, vegetation) (Eschmeyer 1952; Colby et al. 1979). In rivers with ice cover during winter, spawning generally occurs immediately following spring break-up, usually from March to June (Bidgood 1968, 1973; Jessop et al. 1974; Machniak 1975). Colby et al. (1979) cite spawning occurring from January to June throughout the range of this species. Walleye spawning was not documented in the Columbia River during the present study; however, suitable spawning substrate is widely available throughout the Columbia and Kootenay rivers.

3.4.2.4 Rearing

The absence of juvenile walleye in the catch indicates that rearing occurs elsewhere in the Columbia River system. Since walleye larvae are poor swimmers (Houde and Forney 1970), any larvae that may be produced in the study area likely would be carried downstream by the current of the Columbia River.

3.4.2.5 Feeding

Plankton and small insects form the majority of the diet of juvenile walleye (Eschmeyer 1952; Jessop et al. 1974; Colby et al. 1979). As they mature, the diet changes to mainly fish, with mature insects being important during various seasons. Within the Columbia River mainstem, ample food likely would be available for both juvenile and adult walleye.

3.4.2.6 Life History

The four walleye captured during this study ranged in length from 394 to 506 mm, and weighed between 640 and 1630 g. The smallest fish was aged as 7+; the remaining three were 9 or 10 years old. No sex or maturity data were obtained.

3.4.3 BROOK TROUT

Brook trout were introduced into tributaries of the Columbia River a number of years ago by the B.C. Fish and Wildlife Branch (H. Andrusak, pers. comm.). They apparently have developed self-sustaining populations in a number of these streams (e.g., Beaver Creek, Norns Creek above falls at Km 2.2) (B. Salekin, pers. comm.; F. Salekin, pers. comm.).

In the present study, only one brook trout was captured (by electrofishing) at Km 16.5 on 31 August 1980. This 2-year-old individual had a length of 293 mm and weighed 320 g. Juveniles (up to 200 mm in length) and young-of-the-year (up to 50 mm in length) have been reported from the lower reaches of Norns Creek (W. Merilees, pers. comm.). Electrofishing in the lower 2.2 km of Norns Creek during the present study did not reveal the presence of this species.

3.4.4 LAKE WHITEFISH

Eleven adult lake whitefish were captured in the Columbia River; they contributed less than 0.1% to the total catch (Table 3.9). All individuals were captured in gill nets set in the mainstem between Castlegar and the Hugh Keenleyside Dam (Table 3.12). Two individuals were captured in the May 1980 sample period while eight were captured during the winter survey. These fish likely originated either from the Lower Arrow Lake, where lake whitefish were introduced a number of years ago (Carl et al. 1977), or from Lake Roosevelt. Movement patterns for this species in the study area are presently unknown.

The capture of low numbers of lake whitefish in spent condition suggests a limited use of the study area for spawning.

3.4.5 CHINOOK SALMON

During the creel survey conducted by the B.C. Fish and Wildlife Branch, it was noted that anglers had caught a total of 39 chinook salmon (*Oncorhynchus tshawytscha*) within the study area (B.C. Fish and Wildlife Branch 1981); none were captured during fish sampling associated with the present study. During the period 1972-1978, the Washington Department of Fisheries stocked approximately 2 148 500 fall chinook salmon in Lake Roosevelt (L. Blankenship, Washington Department of Fisheries, Olympia, pers. comm.). The planting sites, date, number planted, brood year, and size were as follows:

<u>Planting Site</u>	<u>Date</u>	<u>Number Planted</u>	<u>Brood Year</u>	<u>Planting Size</u>
Sanpoil, Kettle and Spokane rivers	Jan. 1972	1 747 200	1971	1200/kg
Sanpoil River	Sept. 1975	180 000	1974	44/kg
Seven Bays	July 1977	56 337	1976	59/kg
Sanpoil River	Oct. 1977	74 889	1976	38/kg
Seven Bays	Aug. 1978	91 000	1977	110/kg

The chinook salmon captured by anglers in the study area undoubtedly originated from the stocks established in Lake Roosevelt. There is no information regarding their abundance, distribution, or habitat preference within the study area.

3.5 NON-SPORT SPECIES

3.5.1 PEAMOUTH

The peamouth has a widespread distribution in British Columbia, and occurs in almost all major river systems. This species typically inhabits weedy littoral zones of lakes and rivers (Carl et al. 1977). Peamouth were encountered throughout the present study area.

3.5.1.1 Abundance and Distribution

The peamouth contributed 1.5% to the total number of fish captured or observed in the present study (Table 3.9). Although peamouth were encountered throughout the study area, based on the summer electrofishing catch, they were most numerous in the low velocity habitat in the upper reaches of the mainstem Columbia River (Table 3.19).

3.5.1.2 Spawning and Rearing

Schultz (1935) stated that spawning of peamouth in Lake Washington occurred in shallow nearshore areas over cobble substrate. Although spawning activity was not observed in the study area, suitable spawning habitat for peamouth was available in the upper sections of the Columbia River. The presence of gravid peamouth in only the May catches suggests spawning occurs in the study area during the period late May to early June. This is in agreement with Carl et al. (1977) who state that, in British Columbia, peamouth generally spawn in May or June.

3.5.1.3 Feeding

Stomachs from 21 mature peamouth were examined; 81% of these were empty. Food items identified in the remaining stomachs included snails and terrestrial insects.

3.5.2 NORTHERN SQUAWFISH

The northern squawfish is one of the most common fish species in British Columbia, but has little value as a sport fish. It is a major predator of small fishes, including salmonids; for this reason it has been the focus of major control programs (Foerster and Ricker 1942). The northern squawfish characteristically inhabits lentic habitat although it may inhabit low to moderate gradient riverine systems (Carl et al. 1977).

3.5.2.1 Abundance and Distribution

Northern squawfish contributed 0.2% to the total number of fish captured in the study area (Table 3.9). They were most abundant in electrofishing catches from low gradient reaches of the Columbia River mainstem (i.e., upstream of Castlegar). Only six northern squawfish were captured by electrofishing in sample sections downstream of Castlegar (Table 3.20).

Gill net catches indicated the presence of large numbers of northern squawfish in the spring, particularly in the net set immediately below the Hugh Keenleyside Dam spillway (G5, Table 3.12; Table B1, Appendix B). Northern squawfish were more abundant in night electrofishing catches during the summer survey in comparison to the other three surveys (Table 3.10).

3.5.2.2 Movements

The variation in seasonal abundance of northern squawfish may reflect inshore movements related to feeding. Northern squawfish were most abundant when forage fish, such as redbreasted shiner, and young-of-the-year of many other fishes were most abundant in the catches (i.e., summer and fall of

1980, spring of 1981). Low numbers of northern squawfish recorded from these areas during the winter survey may result from movement back into deeper waters, possibly in response to movements of prey species.

3.5.2.3 Spawning and Rearing

Patten and Rodman (1969) reported that northern squawfish spawned in Merwin Reservoir (in the lower Columbia River drainage, U.S.A.) throughout June and July, with peak spawning in early July. Northern squawfish reputedly spawn on a variety of substrates, ranging from small gravels (Carl et al. 1977) to large, angular rocks (Patten and Rodman 1969). They may spawn in inshore shallows or stream mouths (Carl et al. 1977) or in areas up to 15 m deep (Patten and Rodman 1969). The abundance of suitable spawning habitat in the upper sections of the mainstem Columbia River, and the presence of numerous yearlings and subadult northern squawfish, suggests spawning by this species likely occurs in the study area. Although no spawning activity was observed during the May survey, the presence of a gravid female in the catch during this study period suggests spawning would occur at a later date, likely in June or July.

Although no young-of-the-year of this species were encountered in the study area, the presence of juveniles indicates a rearing use of the Columbia River mainstem.

3.5.2.4 Feeding

The diet of the northern squawfish consists primarily of fish (Scott and Crossman 1973). Although northern squawfish stomachs were not examined in this study, probable food items utilized by this species in the Columbia River would include reidside shiner, sculpins, young salmonids (including kokanee), young whitefish and suckers, and some terrestrial and aquatic insects.

3.5.3 SUCKERS

Three species of sucker were encountered in the study area; these included the largescale sucker (*Catostomus macrocheilus*), longnose sucker

(*C. catostomus*), and bridgelip sucker (*C. columbianus*). As a group, suckers contributed 12.1% to the total number of fish captured or observed in the present study (Table 3.9).

3.5.3.1 Abundance and Distribution

The largescale sucker was the most prevalent species of sucker in the study area, contributing 67% to the total number of identified suckers in the catch (Table 3.9). Longnose suckers were encountered less frequently, contributing 30% to the total identified sucker catch. Bridgelip suckers were relatively scarce (3%).

Gill net catch rates for both longnose and largescale suckers were highest during the spring (1980) sample period (Table 3.12). The presence of gravid and ripe adults in the catches at this time suggests that spawning may occur in the backwater areas where the gill nets were set. Gill net capture rates for both of these species decreased substantially in the following seasonal surveys. In contrast, electrofishing data indicate that suckers were least abundant in the fall and spring (1981) surveys. These variations likely are due to seasonal differences in habitat selection and food availability which affect susceptibility to sampling methods.

Longnose suckers were encountered mainly in slow-flowing habitat in the upper reaches of the Columbia River (Table 3.19). Bridgelip sucker and largescale sucker exhibited a preference for the faster flowing reaches of the Columbia River below Castlegar (Table 3.20).

3.5.3.2 Movement Patterns

A comparison of night versus day electrofishing catches of both longnose and largescale suckers (Tables 3.10 and 3.11) indicates that largescale suckers were equally abundant in both day and night catches, while longnose sucker were captured predominantly in night sampling. Carl et al. (1977) report that the longnose sucker generally occupies deeper waters than the largescale sucker; the increased catches of longnose suckers in the night surveys may result from nocturnal inshore movements from deeper water habitats occupied during the day.

Spawning movements of suckers into one tributary (Norns Creek) in the study area were observed. Other movement patterns by adult sucker species were poorly defined. The decreasing abundance of young-of-the year suckers at summer and fall beach seine sites (Table 3.13) may reflect seasonal changes in habitat preferences as the size of juveniles increased, or may reflect decreased numbers due to predation.

3.5.3.3 Spawning

The three species of sucker encountered in this study are spring spawners. Longnose suckers generally spawn from mid-April to mid-May over large gravel substrate; largescale sucker spawn over more varied substrates from mid-May to late June (Scott and Crossman 1973). The abundance of these two species in the study area likely reflects the abundance of suitable spawning habitat in the Columbia River.

In the present study, ripe and spent adult longnose sucker were captured from 1 to 11 May. Although suckers observed spawning in Norns Creek (19 June) were not positively identified, it is suspected that these individuals were longnose sucker. In the mainstem Columbia River, largescale suckers in spawning condition were present in both spring and summer catches, indicating a more extended spawning period for this species.

3.5.3.4 Rearing

The abundance of young-of-the-year and juvenile longnose and large-scale suckers in seine haul catches from the study area indicates a high rearing use of the mainstem Columbia River (Table 3.13). The presence of young-of-the-year suckers in Norns Creek indicates a use of this area for rearing.

3.5.3.5 Feeding

Stomach content analysis was not conducted on sucker species. All three species found in the study area are bottom feeders and as such feed primarily on aquatic invertebrates.

3.5.4 CARP

Carp were introduced into the lower Columbia River system in the nineteenth century and have since dispersed throughout the Columbia and Fraser river systems. They have little human importance in British Columbia and generally are considered a nuisance or trash fish. Scott and Crossman (1973) suggest carp are detrimental to native fish populations because they increase water turbidity and destroy aquatic vegetation that provides potential cover, food, and spawning sites for valued fish species.

3.5.4.1 Abundance and Distribution

In the present study two carp were captured. One individual was caught at Km 54.5 during the fall survey and the other at Km 50.2 during the spring (1981) survey. The areas of capture were characteristically slow flowing with shallow, vegetated bottoms. Local residents report that carp are common in the Castlegar area during June and July (B. Salekin, pers. comm.; W. Merilees, pers. comm.). However, suitable habitat within the study area apparently is restricted to a number of shallow backwater areas near Castlegar and at the confluences of tributaries to the upper section of the Columbia River. A resident population in this area would be restricted severely due to water level fluctuations which limit aquatic vegetation.

3.5.4.2 Movement Patterns

No evidence of carp movements in the study area was obtained; however, the reported abundance of this species in late spring to early summer and their absence in the late fall and winter periods suggests movements within the study area occur, although the extent of these movements is unclear. McCrimmon (1968) describes onshore and offshore movements of this species related to temperature regimes in Lake St. Lawrence (i.e., movements to warm surface waters in spring and summer and to warmer waters at depth in winter). The decrease in mainstem water temperatures in fall periods may result in this species moving out of the study area in search of warmer waters (e.g., in Lake Roosevelt).

3.5.4.3 Spawning and Rearing

Preferred spawning habitat for carp consists of shallow areas with temperatures of at least 17°C (McCrimmon 1968). W. Merilees (pers. comm.) observed large numbers of carp swimming and splashing on the water surface in a backwater near Castlegar. This type of prespawning activity is typical for carp (McCrimmon 1968). W. Merilees (pers. comm.) also reported that young carp (i.e., 5 to 6 cm in length) were present in pools adjacent to the mainstem in September. This can be interpreted as indirect evidence that spawning occurs in the study area and that the mainstem also provides rearing habitat.

3.5.4.4 Feeding

Scott and Crossman (1973) indicate that carp are omnivorous. They consume a variety of plant and animal fauna including aquatic insects, crustaceans, aquatic plants, etc.

3.5.5 REDSIDE SHINER

3.5.5.1 Abundance and Distribution

The redbside shiner is the most abundant species of fish in the Columbia River within the study area, contributing 78.4% to the total number of fish captured or observed (Table 3.9).

Redside shiner were most abundant in the low gradient reaches of the Columbia River upstream of Castlegar. In the higher gradient downstream reaches, they were encountered only in isolated pools and backeddies. Small individuals of this species also are reported to be present in Norns Creek throughout the year (W. Merilees, pers. comm.).

3.5.5.2 Movement Patterns

Scott and Crossman (1973) indicate that redbside shiners in lakes undertake seasonal onshore and offshore movements in response to increasing or decreasing water temperatures. This type of movement pattern may

account, in part, for the seasonal variation in catch rates of this species within the study area.

3.5.5.3 Spawning and Rearing

Redside shiners generally spawn from May to late July (Scott and Crossman 1973). In the present study, redside shiner spawning was not observed; however, the presence of numerous young-of-the-year in the upper sections of the mainstem suggests spawning may occur in this area. Suitable rearing habitat also is present in the upper reaches.

3.5.5.4 Feeding

Redside shiners exhibit a varied diet including aquatic and terrestrial insects, fish eggs, and other small fishes. This species also is an important food source for larger fish such as rainbow trout, Dolly Varden, walleye, and northern squawfish.

3.5.6 SCULPINS

Three species of sculpin were encountered in the study area. Two of these, the shorthead sculpin (*Cottus confusus*) and prickly sculpin (*C. asper*) were encountered in the mainstem Columbia River. Together they contributed 2.2% to the total catch in the study area (Table 3.9). The third species, torrent sculpin (*C. rhotheus*) was encountered only in Norns Creek.

Due to difficulty in identification, the shorthead and prickly sculpins were not differentiated in the field. The habitat preferences of these species reportedly are quite different (Scott and Crossman 1973). The shorthead sculpin characteristically inhabits cool, fast-flowing streams, while the prickly sculpin generally prefers quiet waters and avoids strong currents. As sculpins generally were more abundant in areas with low current velocity (Tables 3.19 and 3.20), it is thought that the prickly sculpin was the most abundant of the two species in the mainstem.

The presence of all size classes of the sculpins in the study area indicates the occurrence of all life functions (spawning, rearing, etc.). The

largest individual collected in the study area was a prickly sculpin, 157 mm in length.

The stomach contents of 13 sculpins were analyzed. Food items consisted mainly of aquatic insects (e.g., stonefly and mayfly nymphs).

3.5.7 LONGNOSE DACE

This species was not encountered in the mainstem Columbia River; however, five individuals were captured by backpack electrofishing in the lower reaches of Norns Creek. Four of these specimens were captured during the summer survey, while the other one was taken during the fall survey. Longnose dace were not encountered in any other streams within the study area.

3.6 HABITAT DESCRIPTION

3.6.1 MAINSTEM COLUMBIA RIVER

Available fish habitats in the mainstem Columbia River were surveyed in early September 1980. Upper sections of the mainstem (i.e., Castlegar to Hugh Keenleyside Dam) were resurveyed during low flow conditions on 4 May 1981. On the basis of gradient, flow type, channel character, water quality, and extent of fish utilization, the mainstem Columbia River between Hugh Keenleyside Dam and Trail was divided into six reaches (see Section 3.7, Figure 3.32).

3.6.1.1 Reach A

This reach consists of a 3.2-km section of the Columbia River, between the Hugh Keenleyside Dam and the B.C. Timber Ltd. effluent diffuser at Km 53.0. The gradient for this reach averaged 0.18 m/km. The channel was characterized by uniform, placid flow, with the mid-channel depth ranging between 10 and 18 m (2 September 1980). Inshore areas featured a rapid drop-off; shallow areas occurred infrequently.

The river banks generally were in repose, with the bank height ranging between 3 and 10 m. They were composed primarily of glacial till although

an area of bedrock was present on the left bank (bank designation assigned while looking downstream) immediately below the dam. Limited riparian vegetation was present above high water marks.

Extremely low water levels occurred during the 1981 spring survey; this facilitated the documentation of substrate composition in inshore areas. Although boulder and cobble were dominant, sand and gravels also were present. In most areas, substrate within the wetted channel appeared to be heavily silted. Aquatic vegetation exhibited a localized distribution in shallow water areas.

Reach A generally exhibited a low current velocity, permitting potential utilization of the entire channel for rearing. Night electrofishing results indicated extensive utilization by forage fish such as reidside shiners, juvenile suckers, and mountain whitefish (Appendix A).

The low to moderate salmonid spawning potential in this reach was limited by generally steep bank types, heavy siltation, and large substrate size. Other factors which would serve to limit spawning success in this reach are the large water level fluctuations, and periodic occurrence of high dissolved gas saturations. Areas of potentially suitable spawning habitat were infrequent (e.g., cove on left side at Km 55.8). However, much of the nearshore area appeared to provide suitable conditions for spawning by forage and coarse fish (e.g., reidside shiner and northern squawfish).

3.6.1.2 Reach B

This reach consists of a 4.0-km section of the Columbia River, from the B.C. Timber Ltd. effluent diffuser to the Castlegar ferry (Km 49.0). Reach B was typified by a uniform, placid flow, much the same as occurred in Reach A.

The major reason for differentiating between Reach A and B is the presence of the mill effluent in the latter reach and its effects on the benthic invertebrate fauna. Beak Consultants Ltd. (1980) documented a reduction in the Group 3 organisms (i.e., pollution intolerant - e.g., mayflies and stoneflies) and an increase in the Group 1 organisms (i.e., high pollution tolerance - e.g., Chironomids) immediately downstream of the B.C. Timber Ltd. effluent

diffuser. The Group 3 organisms had recovered several kilometres downstream due to the dispersal of the effluent throughout the water column.

The banks in Reach B were non-uniform (i.e., ranging from flat to steep) and consisted of finer materials (i.e., more sand and organic material) in comparison to Reach A. Large areas of relatively flat sand-silt deposition bars were present (i.e., left bank Km 53 to Km 52.5). The irregular channel created shallow, protected bay areas with relatively low current velocity. These areas primarily featured sand and silt substrate and substantial growth of aquatic vegetation. In areas where banks were more repose in nature, the substrate in the river was composed of large and small gravels, usually with a high percentage of sands and silts.

Night electrofishing in this reach (Appendix A) resulted in the highest catches of juvenile age classes of kokanee, mountain whitefish, rainbow trout, suckers, and forage fish in the study area. A number of factors appear to contribute to the high rearing potential of Reach B. These include low stream velocity, extensive occurrence of shallow areas, and presence of aquatic vegetation. Site-specific features such as log booms, man-made structures (e.g., boat docks), and debris provide additional cover.

The spawning potential of Reach B for salmonid fishes is low due to the absence of defined gravel areas, the high degree of silt and sand in the substrate, and the periodic exposure of extensive shallow areas when water levels drop.

3.6.1.3 Reach C

Reach C constitutes a 4.0-km section of the Columbia River, from the Castlegar ferry (Km 49.0) to a point immediately downstream of the Kootenay River confluence (Km 45.0). The average gradient in this section is 6.3 m/km; this reach was typified by moderately swift runs. A typical mid-channel depth was 8.4 m in the fall of 1980. The channel appeared stable and often was confined by high banks. The banks, which were repose in nature, consisted of cobble and boulder. The substrate within the wetted channel also consisted of cobble and boulder, with occasional areas of gravel concentration.

Two major backwater areas (Km 47.5 and Km 46.5) and one major area of rapids (i.e., Tin Cup Rapids, Km 46.7) were present in this reach although numerous sets of rapids and riffle areas also were present. The backwater area situated at Km 47.5 (left side) was fairly extensive; the average depth in this area (approximately 2 to 3 m) was sufficient to ensure that it remained flooded during periods of very low water (e.g., 3 to 5 May 1981). The substrate within the backwater ranged from silt and organic debris in shallow water areas to cobble and gravels in deep water areas. Within this backwater extensive aquatic vegetation and wood debris were present, providing good instream cover. Gillnetting in this area resulted in the capture of two mature kokanee (fall 1980) and four mature rainbow trout (spring 1980). This suggests that the backwater functions as a resting or holding area during spawning migrations. Also, the capture of 42 mature longnose and largescale suckers in this backwater indicates the possible spawning utilization of this reach by coarse fish. Adult mountain whitefish and lake whitefish also were captured at this site in the spring of 1980.

Another large backwater area was located along the right bank, immediately downstream of Tin Cup Rapids; however, its presence appeared to be dependent on the availability of high water levels. In May 1981 (a low flow period), most of this area was exposed. In contrast to the previously described backwater, there was little aquatic vegetation present in this area; the substrate primarily consisted of cobble and sand.

Two larger tributaries enter the Columbia River within Reach C -Norns Creek at Km 48.6 and the Kootenay River at Km 45.5. At the Norns Creek confluence there were extensive gravel and cobble shoals.

The spawning potential for salmonids was moderate in Reach C due to the presence of several gravel bars with suitable water depth and velocity in the mainstem. In addition to the discrete bar areas, there also were extensive shallow areas with gravel and cobble substrates. Although there is no direct evidence of mainstem spawning in this reach, the presence of mature adult fish in the area during spawning periods suggests some potential.

This reach possesses moderate potential for rearing due to the presence of backwaters characterized by slow-flow velocity and abundant aquatic vegetation.

3.6.1.4 Reach D

Reach D, a 9.5-km section, is situated between the Columbia-Kootenay River confluence (Km 45.5) and a point immediately above the confluence of Blueberry Creek (Km 36.0). The average gradient in this section is 7.0 m/km. The reach is characterized by moderately fast water velocities; occasional areas of rapids or riffles are present. Numerous small backeddies and infrequent large backeddies were situated along both banks. Point sampling showed that mid-channel depths within this reach averaged approximately 10 m on 1 September 1980.

Within this reach, the channel was confined by steep valley walls. The immediate banks were composed of cobble and boulder, sloping sharply into the channel. Significant shallow areas were absent in this reach. As a result, there was little aquatic vegetation present.

The substrate in this reach was composed primarily of boulders and cobble, and generally was not suitable for salmonid spawning. Shallow areas adjacent to a large backeddy (Waterloo Eddy; left bank, Km 39.3) contained localized areas of gravel and small cobble, and may be suitable for salmonid spawning. Local fishermen reported the capture of ripe rainbow trout in Waterloo Eddy, suggesting possible spawning utilization of the area. Another isolated, potentially suitable salmonid spawning area was present at a gravel and cobble bar extending from the left bank at Km 37.3.

Based on the presence of only a few isolated areas of suitable gravel substrate and the relatively high flow velocities throughout, the potential for salmonid spawning in this reach was considered to be low. The rearing potential was classed as moderate due to the presence of numerous small backeddies formed by bank irregularities.

3.6.1.5 Reach E

This reach extended from Blueberry Creek (Km 36.0) to the upstream end of the rapids at Km 25.7. A mean gradient of 7.0 m/km within this reach resulted in moderately swift flows; a major riffle area occurred at Km 30.0. Numerous small and large backeddies were present along both banks. The average mid-channel depth was estimated to be 11 m. Within this reach the Columbia River generally occupied a relatively straight and confined channel. The banks generally were in repose, consisting mainly of cobble and boulder near the channel. Blueberry, Champion and China creeks enter the mainstem in the upper 4.0 km of this reach; at the confluence of these creeks, cobble and gravel fluvial fans extend into the main channel.

An atypical area exhibiting increased channel width and a moderate degree of braiding was present near the settlement of Genelle. This 3-km section of the river contained numerous small riffles and several large eddies and backwaters. Bars present in this area were not vegetated and were composed mainly of loose gravel and cobble. Shallow water areas along these bars may provide suitable conditions for salmonid spawning. A shoal, consisting of gravels and cobble, also was present along the right bank at Km 26.5. As a result of the gravel areas present, this reach was considered to have a moderate spawning potential for salmonids.

The rearing potential of Reach E appeared to be moderately high. Eddy and backwater areas associated with riffles likely provide suitable rearing habitat for species such as rainbow trout and mountain whitefish.

3.6.1.6 Reach F

This reach consists of an 8.7-km section of the Columbia River from the rapids at Km 25.7 to Trail (Km 17.0). It is typified by a fast flow with frequent riffle or rapid areas. There were numerous small backeddies situated along the banks throughout this reach. The mid-channel depth was estimated to average 13 m; water depth increased rapidly offshore resulting in very few shallow areas being present. The channel was sinuous, being confined by cobble banks and bedrock outcroppings.

Murphy, Hanna, Billy, and Topping creeks enter the mainstem Columbia River within this reach. Fluvial fans at the confluences of Murphy and Hanna creeks extend into the mainstem channel.

An area of low current velocity and moderate depth occurred at Km 18.2 near Trail. Aquatic vegetation was well developed in this backwater in response to these conditions. Numerous small rainbow trout were observed surface feeding at this location on 1 September 1980; however, only four juvenile rainbow trout were captured in gill nets.

The spawning potential of this reach for salmonid species was considered to be low due to the swift flows and absence of gravel substrate in the channel. Rearing potential was considered to be moderate due to the presence of a number of eddies and backwater areas.

3.6.1.7 Below Trail

The section of the Columbia River between Trail and the International Boundary is similar to Reach F. The flow was generally swift with scattered areas of large riffles and rapids. Numerous small eddies were located along both banks; isolated backwater areas also were present. Large bedrock outcrops occur in the main channel at Km 13.0. The flow around these outcroppings was swift and turbulent, forming large whirlpools (up to 40-m diameter at high water levels).

Ryan, Bear, Beaver, Casino, and Sheppard creeks enter the Columbia River mainstem below Trail. The Pend Oreille River (regulated by the Waneta Dam) flows into the Columbia River at Km 0.7.

3.6.2 KOOTENAY RIVER

The Kootenay River flows in a westerly direction out of the Selkirk Mountains before entering the Columbia River at Km 45.0. It is the largest tributary to the Columbia River within the study area, draining a watershed of approximately 49 469 km². The mean discharge at the outlet of Kootenay Lake was 797 m³/s for the period 1937 to 1979 (Water Survey of Canada 1980). The Brilliant Dam is located 2.6 km upstream from the Columbia

River-Kootenay River confluence; it represents the upstream limit of movement of fish from the Columbia River.

To facilitate discussion, the section of the Kootenay River below the Brilliant Dam was divided into two reaches (Figure 2.2) on the basis of channel configuration and flow characteristics.

3.6.2.1 Reach A

This reach consists of a 1.1-km section from the Brilliant Dam to the Highway 3A bridge. It is typified by a turbulent flow through a restricted, deep bedrock channel. No aquatic vegetation was observed within this reach.

This section of the Kootenay River has extremely limited potential for salmonid spawning. The flow character was generally broken in mid channel and swirling along the jagged banks. There did not appear to be any gravel areas present; however, only the nearshore areas could be surveyed effectively. The rearing potential for salmonid juveniles also was considered to be low due to the limited availability of low velocity areas.

3.6.2.2 Reach B

This reach consists of a 1.5-km section from the highway bridge to the confluence with the Columbia River. It exhibits moderate flow velocities with isolated backeddies or calm backwaters. The channel is typically wider and more uniform than in Reach A, although a major side channel is present near the mouth of the river. The banks primarily were composed of cobble and boulder, with bedrock and gravels in isolated areas. A bedrock outcropping, present along the right bank approximately 400 m downstream of the highway bridge, created an area of turbulent swirling water. The banks typically were in repose and were 5 to 20 m in height.

Substrate in this reach ranged from boulders and large cobble in upper sections to cobble and large gravel in the lower 0.6 km of the river. A submerged shoal consisting of large gravels and cobble was present on the right side of the river approximately 50 m below the highway bridge. Rainbow trout were observed spawning on this shoal during the 1981 spring

study period. Another shoal, consisting of large cobbles, was located across the river. No spawning was observed on this shoal. An area of large gravels was present near the mouth of the Kootenay River, and may be suitable for rainbow trout spawning.

A large horseshoe-shaped side channel was connected to the main channel along the south bank a short distance upstream from the confluence. It was approximately 1 km in length, surrounding a flat, vegetated area. Flow within the channel only occurs during high discharge periods; at lower water levels, the upstream end of the channel becomes dry, leaving a calm backwater area in the lower section of the side channel. Extensive growths of aquatic vegetation were noted in the channel during the summer of 1980. At that time, large numbers of adult and juvenile suckers were present.

The rearing potential of this reach for salmonids was considered to be fair to good due to the presence of backwater areas and scattered eddies along both sides of the river. The spawning potential for salmonids was considered fair due to the existence of a number of gravel bars, some of which presently are utilized by large rainbow trout. Mountain whitefish likely also spawn within this section of the river.

3.6.3 OTHER TRIBUTARY STREAMS

The lower sections of five of the tributary streams within the study area (i.e., Norns, Champion, Murphy, Blueberry, and China creeks) were surveyed for potential fish habitat in early September 1980. These surveys were conducted during a low flow period, to facilitate easier access throughout the streams' lengths.

Norns and Champion creeks were surveyed up to the first point of impasse for upstream movement of fish from the Columbia River (i.e., waterfall or cascade). Blueberry, China, and Murphy Creeks were surveyed up to a point a short distance upstream of the highway crossing.

An assessment of the habitat suitability for salmonid spawning and rearing was conducted through a preliminary application of the Habitat Evaluation Procedure (H.E.P. 1980, U.S. Fish and Wildlife Service). This

process involves assigning Habitat Suitability Indices (HSI) to individual sections or areas of the stream for a given species group (e.g., salmonids) and species life requisite (e.g., spawning or rearing). The procedures followed in developing habitat suitability for the streams, and the results, are reported in Appendix F.

3.6.3.1 Norns Creek

Norns Creek (locally called Pass Creek) flows in a southwest direction and enters the Columbia River at Km 48.6 (Figure 2.1). The creek drains approximately 19 400 ha of mainly forested land along the Selkirk Mountains. A number of swampy areas occur in the drainage but no distinct lakes are apparent. Two sets of falls occur within the lower 15.6 km of the stream. The first, located at Km 2.2, is 30 to 35 m in height and presents an impasse to fish moving upstream from the Columbia River. The second set of falls (Km 12.6) is approximately 15 m in height.

Six tributaries enter Norns Creek within the first 15.6 km. Gibson Creek, entering at Km 4.7, is the only named tributary; the five unnamed creeks enter at Km 8.7, Km 11.5, Km 13.0, Km 14.0, and Km 15.2.

(a) Gradient

The gradient profile of Norns Creek is illustrated in Figure 3.11. The average gradient in the lower 1.9 km of Norns Creek (approximately 2.6 m/km) is very low compared to other tributaries in the study area (Figure 3.12). In the section between Km 1.9 and Km 2.2, the gradient increases (averaging approximately 30 m/km), creating a cascade type of flow. At Km 2.2, the creek drops 30 to 35 m over a series of falls. In the 8 km upstream of these falls, the gradient averages about 12 m/km.

(b) Discharge

Discharge in Norns Creek was estimated to be $4 \text{ m}^3/\text{s}$ on 5 September 1980 and $12 \text{ m}^3/\text{s}$ on 17 April 1981, indicating significant variation between seasons. Discharge (either too high or too low) did not appear to block

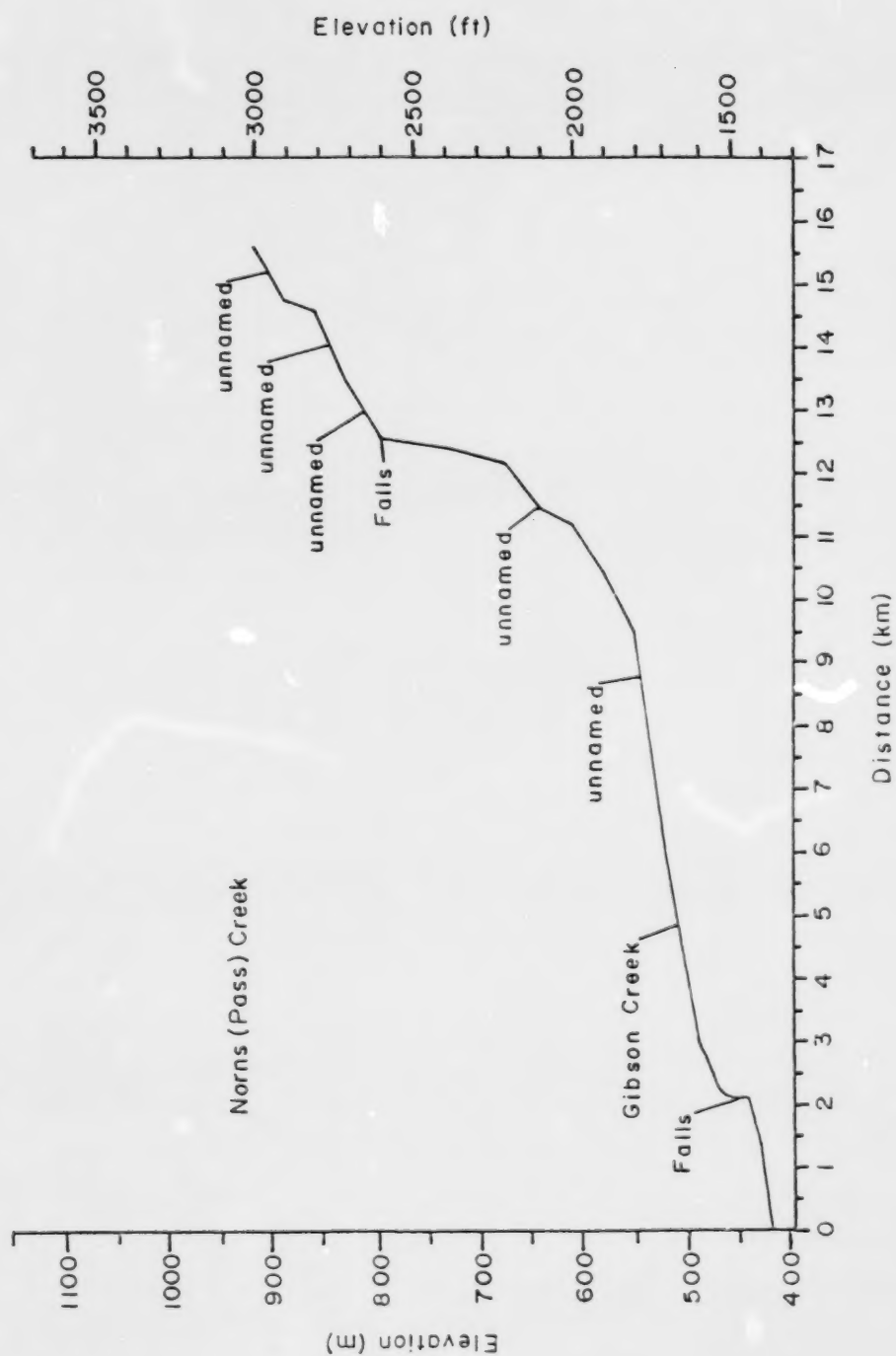


Figure 3.11. Gradient profile of Norns Creek.

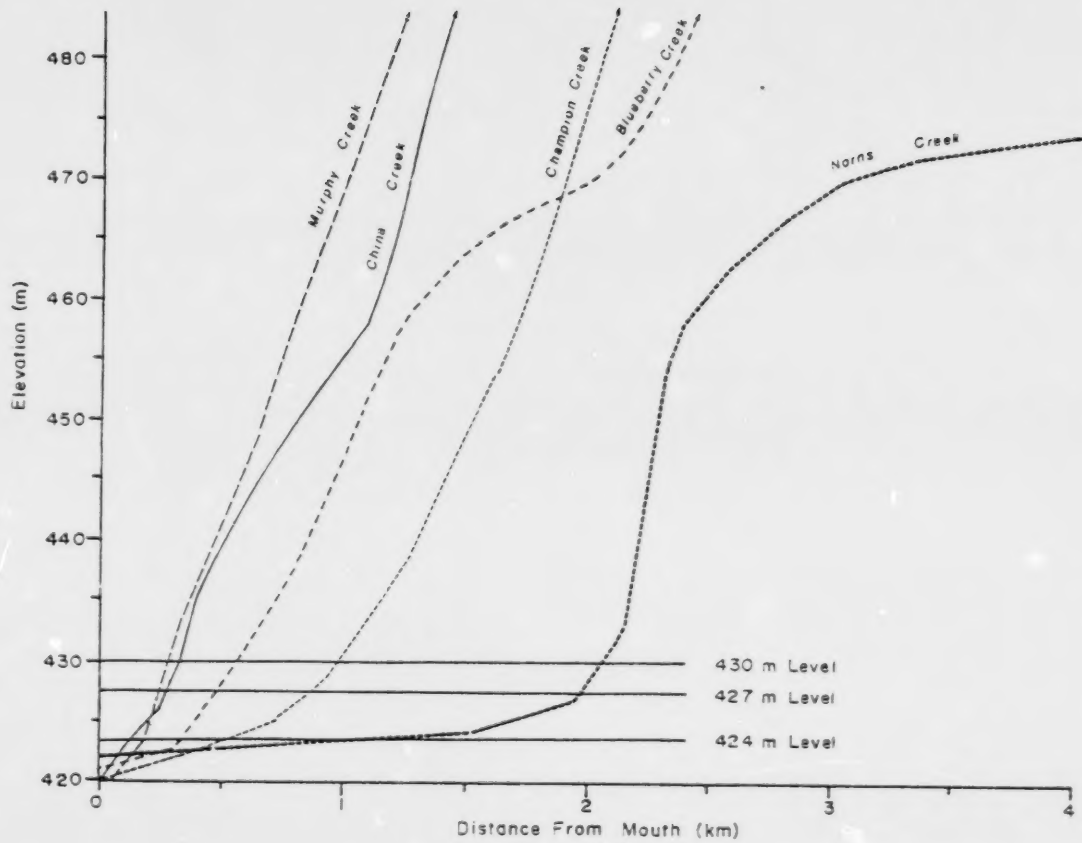


Figure 3.12. Gradient profiles of Columbia River tributaries.

movements of spawning fish into the stream although spring freshets may inhibit access for short periods of time.

(c) Water Temperatures

The lowest water temperature recorded during this study was 0°C on 3 February 1981. The maximum recorded temperature was 14°C on 14 July 1980. Riparian vegetation afforded limited cover to this stream; consequently, water temperatures exhibited considerable daily fluctuations (e.g., on 17 April 1981 the water temperature was 4.5°C at 0730 h and 9.0°C at 1830 h).

(d) Reach Description

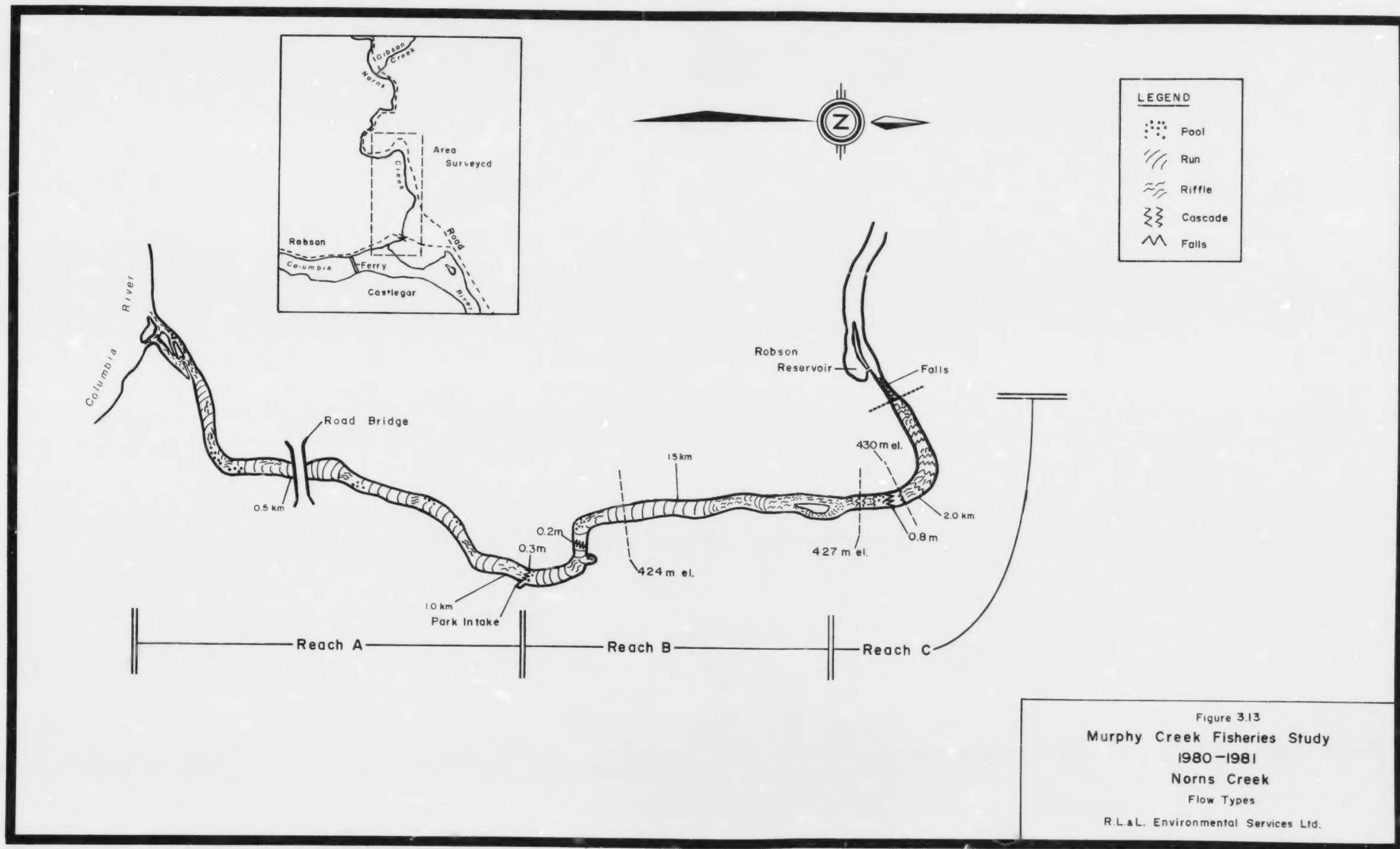
The predominant flow types, bank types, and substrate for the lower sections of Norns Creek as noted during the fall 1980 survey are illustrated in Figures 3.13, 3.14, and 3.15, respectively.

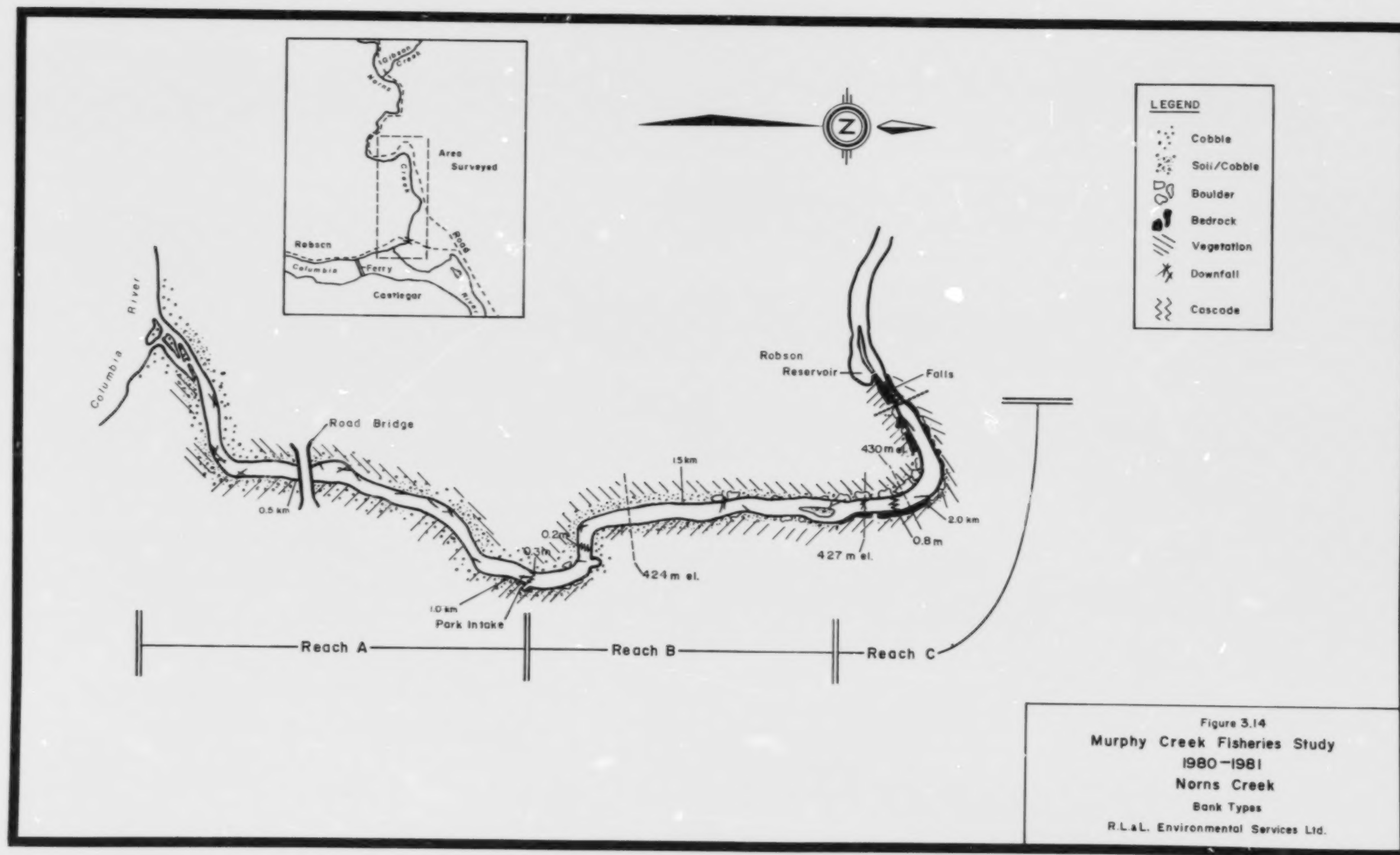
Reach A—This reach was typified by rolling flow, interrupted by a few short riffles, meandering across a relatively wide cobble channel. There was only one major pool in Reach A, occurring 300 m upstream of the stream confluence. It had a maximum depth of 2 m during the fall 1980 survey. The streambanks were composed of glacial till and organic material; however, artificially stabilized banks composed of large, angular boulders were present near high use areas (i.e., Km 0.5 to 0.6). Backpack electrofishing indicated substantial use of this area (i.e., stabilized area) for rearing by rainbow trout. Banks within Reach A ranged between 0.4 and 3 m in height. Degrading banks were present at several locations. Riparian vegetation provided very little cover. Cottonwood, willow, and aspen were distributed along approximately 50% of the streambank.

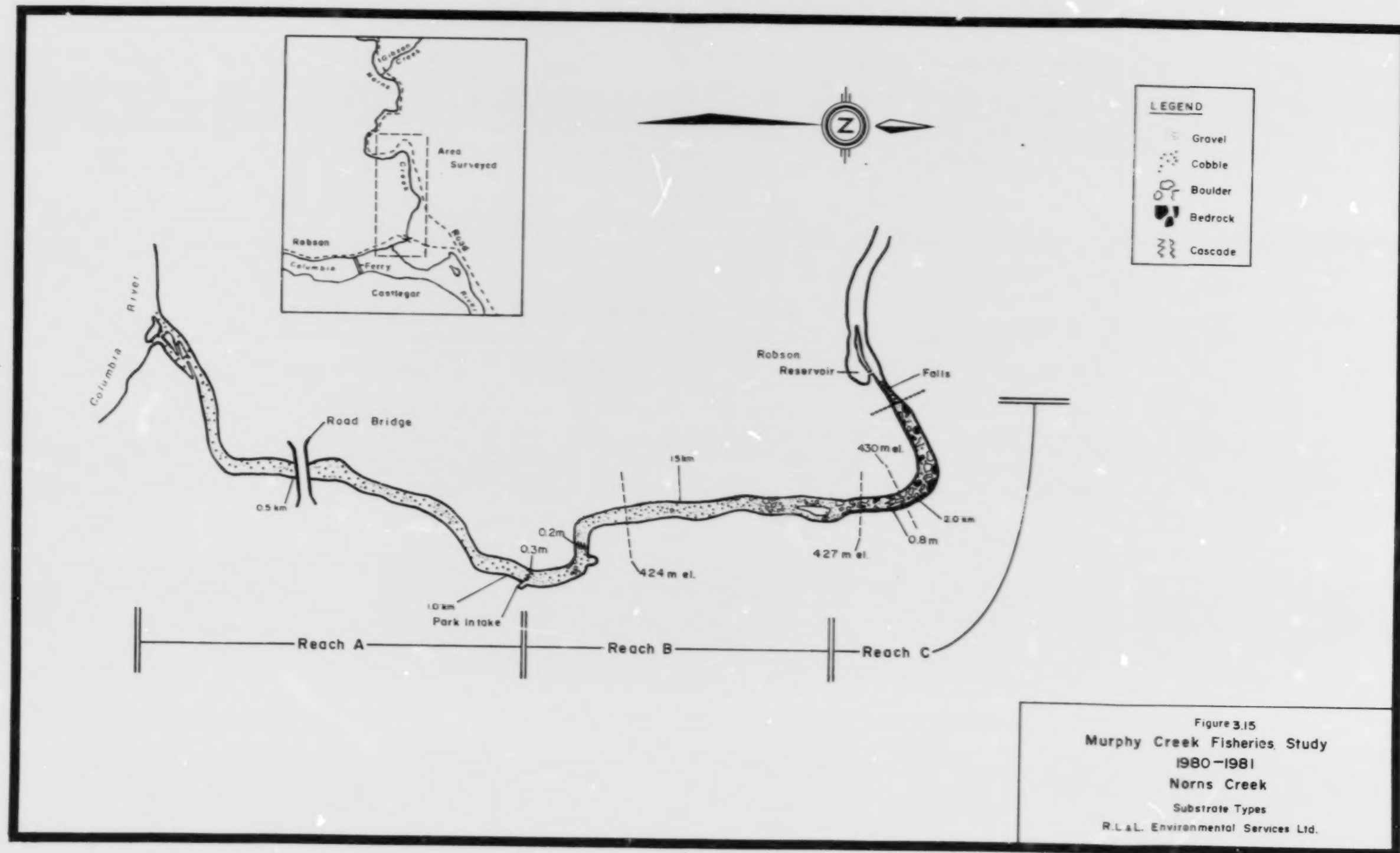
Substrate within this reach consisted of primarily cobble and large gravels, ranging between 3 and 10 cm in diameter, although localized areas of smaller gravels also were present.

Reach A provides moderate spawning potential for kokanee and rainbow trout. Areas where spawning was observed during this study are runs at











Km 0.15 to 0.35, Km 0.38 to 0.50, and Km 0.65 to 0.8. Moderate flows in a single, well-defined channel are characteristic of these runs. Average depths ranged between 0.3 m in fall (i.e., kokanee spawning period) and 0.7 m in spring (i.e., rainbow trout spawning period). Substrate in these runs consisted of mainly large gravels (i.e., 3- to 6-cm diameter). The rearing potential of Reach A is quite low except among the boulders used to stabilize the bank at Km 0.5.

Reach B—Reach B extends from a rock weir (0.3 m in height) at Km 1.05 to the downstream end of the cascades (i.e., Km 1.86). The rock weir facilitates the seasonal diversion of a portion of Norns Creek flow to fill pools in Pass Creek Park. The low gradient in this reach produces moderate velocity runs through most of this section. Three riffle areas (Km 1.15 to 1.20, Km 1.66 to 1.70, and Km 1.75 to 1.79) separate the runs. Major pools, with maximum depths of 2.0 m, occur at Km 1.25, Km 1.85, and Km 1.86. These pools provide important holding areas for spawners (e.g., 45 kokanee were observed in the pool at Km 1.25 on 3 September 1980).

Reach B flows through a single, well-defined channel, averaging 20 m in width. The high banks and hillsides result in occasional confinement and a generally stable channel flowing in an irregular pattern. The scoured bed material consisted mainly of large gravels and cobble (i.e., 2- to 10-cm diameter) in the runs. The frequency of occurrence of large cobbles and boulders within run and riffle areas increased in an upstream direction, resulting in decreasing amounts of suitable spawning substrate.

Banks were generally repose in nature, although occasional undercuts existed. Bank height ranged between 0.4 and 4.0 m and consisted mainly of glacial till and organic material. Areas of bank degradation were infrequent. Bedrock outcroppings formed the downstream left bank between Km 1.82 and Km 2.0. Riparian vegetation covered both banks, but afforded only a small amount of cover to the stream.

Elevation 424 m occurs within Reach B at Km 1.36. The spawning potential of Norns Creek below this point is considered to be high. During

the surveys, high density utilization of this section by spawners (i.e., kokanee and rainbow trout) was observed.

The rearing potential of Norns Creek below the 424-m contour is low to moderate. Generally, low abundance and poor suitability of available cover are not conducive to the rearing of salmonids. This is confirmed by the low occurrence of older juvenile (i.e., 1+ and older year classes) salmonids during backpack electrofishing surveys. Selected shore areas (e.g., Km 1.1 to 1.2, downstream left bank) and intermittent side pools are utilized by newly emerged salmonid fry; however, they do not remain in these areas for very long (i.e., the lack of cover makes the fish susceptible to freshets).

Reach C—Reach C extended from the change in gradient at Km 1.86 to the base of the falls at Km 2.2. The flow in this 340-m section of Norns Creek typically is cascading in a confined channel. The cascades are up to 0.8 m in height. There are occasional pools in this reach, the largest of which had a maximum depth of 2.5 m during the fall survey. Rainbow trout and kokanee spawners utilized these pools (probably for resting) prior to moving to more suitable spawning areas.

The channel of this reach averages approximately 22 m in width and is confined by bedrock outcroppings and steep hillsides. The immediate streambank averaged 1.7 m in height. A dense growth of riparian vegetation (e.g., cedar, hemlock, cottonwood, bitter cherry, salmonberry, thimbleberry) provides significant cover to the stream.

Within the channel, large cobble and boulder are the dominant substrate types; however, pools contained large gravels while backwater areas near shore were heavily silted.

Both the 427-m and 430-m elevation contours occur in this reach. Below the 427-m contour, the spawning potential in this reach for rainbow trout and kokanee was considered to be low. Similarly, the rearing potential appears to be low, as was evidenced by the low occurrence of juvenile salmonids in backpack electrofishing surveys within this region.

The 430-m elevation is located at Km 2.1, near the base of the falls. The region between the 427-m and 430-m contour exhibits low spawning

potential because of the nature of the flow (i.e., cascading) and the lack of suitable substrate. The rearing potential of this region is moderate, with suitable backwater areas among the large boulders along the water's edge; however, these areas appear to be largely inaccessible to juveniles.

Above the 430-m contour there remains only a small portion (i.e., approximately 100 m) of Norns Creek accessible to migrating fish. The potential utilization of this area is very low, due to the cascading nature of the flow.

3.6.3.2 Champion Creek

Champion Creek flows in a westerly direction and enters the Columbia River at Km 32.8 (Figure 2.1). It drains about 6790 ha of the Selkirk Mountains, including the Champion Lakes. Four major tributaries enter Champion Creek. Landis Creek, the only named tributary, drains the Champion Lakes and enters Champion Creek at Km 3.1. Three unnamed creeks enter at Km 6.5, Km 8.3, and Km 9.3.

(a) Gradient

The gradient profile of Champion Creek is illustrated in Figure 3.16. The lower 1.6 km of Champion Creek has a moderate gradient of about 22 m/km. Between Km 1.6 and the impasse (2-m-high falls) at Km 2.5, the stream gradient is very steep, averaging 140 m/km. Above the impasse, the gradient decreases somewhat, averaging 49 m/km for the upper 10 km.

(b) Discharge

Discharge is a major factor which limits the spawning utilization of Champion Creek. During the fall survey, the total discharge 500 m upstream of the confluence with the Columbia River was estimated to be $0.25 \text{ m}^3/\text{s}$; however, 100 m from the confluence the discharge was only $0.01 \text{ m}^3/\text{s}$. This reduction resulted from flow dissipating into subsurface materials in the lower 300 m of the creek. Suitable spawning areas upstream were thus rendered inaccessible to fall spawners (i.e., kokanee). During the 1981 spring survey discharge was sufficient to permit upstream fish passage into Cham-

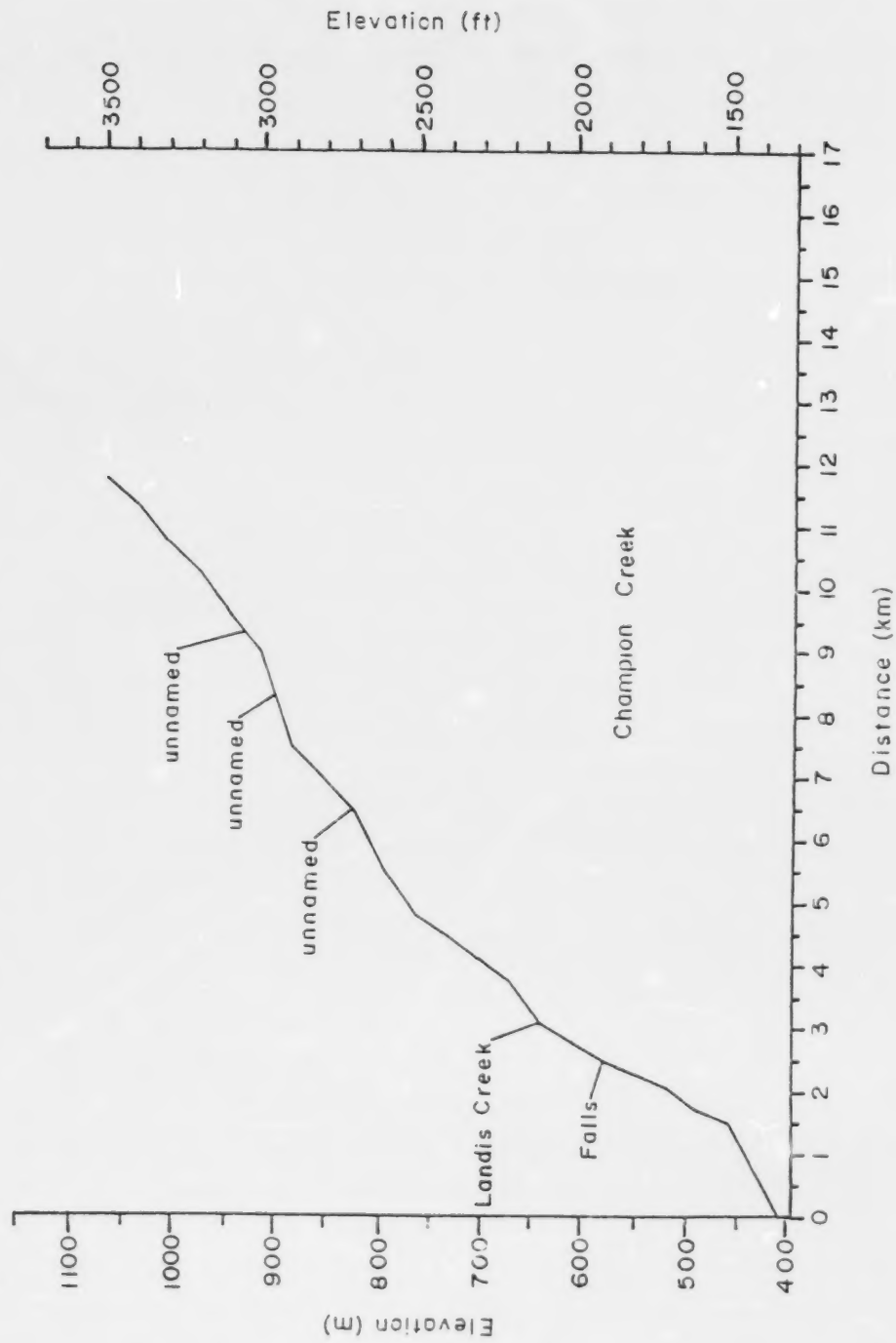


Figure 3.16. Gradient profile of Champion Creek.

pion Creek (i.e., discharge ranged between 2.0 and 4.3 m³/s as measured 100 m upstream from the confluence).

(c) Temperature

The minimum temperature recorded during this study in Champion Creek was 0°C on 1 February 1981. The maximum temperature was 14°C, recorded on 17 July 1980.

(d) Reach Description

Champion Creek was divided into three distinct habitat reaches on the basis of gradient, channel configuration, and flow characteristics. The predominant flow types, bank types, and substrate in these reaches as noted during the fall 1980 survey are illustrated in Figures 3.17, 3.18, and 3.19, respectively.

Reach A—Reach A extends from the mouth of Champion Creek to a 0.6-m-high rock weir located 600 m upstream. It is typified by an irregular channel (frequently confined), moderately swift runs, and a limited number of pools. Estimated mean depths in runs ranged between 10 cm in the fall survey period and 35 cm in the spring survey period. As noted above, pool habitat occurred infrequently; where present, pools provided rearing habitat for young-of-the-year rainbow trout. Major pools noted during the fall 1980 survey were located at Km 0.32 and Km 0.48. Maximum pool depth was 0.75 m on 6 September 1980. A major pool at Km 0.15, which was not present during the low flow periods (see Discharge, Section b above), provided resting and spawning habitat during the rainbow trout spawning migration in spring 1981.

Bank composition in Reach A was predominantly sandy, glacial till, and organic material. The banks are generally stable; however, two areas of active degradation exist at Km 0.21 and Km 0.4. These areas consist of fine grained sand banks up to 6 m in height.

Streambank vegetation provides only limited channel cover in Reach A. During periods of low flow (i.e., the fall survey period), the wetted channel

width generally had very little overhanging vegetation; however, mature trees on the banks did provide some shading of the channel.

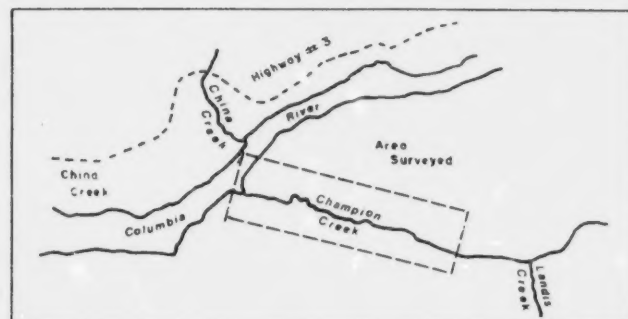
The substrate of Reach A is composed of mainly cobble and large gravels (i.e., D90 of 10 cm) with some scattered sandy areas and occasional large boulders. Also, isolated areas of small gravels (i.e., 0.5 to 8 m² areas) were present, providing spawning habitat for rainbow trout.

Elevation 424 m is located within Reach A. Below this elevation, Champion Creek exhibited moderate rainbow trout rearing and spawning potential (Habitat Suitability Index (HSI) = 0.55, Appendix F). Rearing potential for this species was limited by the low abundance of high quality pool habitat and the limited availability of suitable cover.

Reach B—Reach B, which extends from Km 0.6 to Km 1.6, flows through a 2-m to 3-m-high bench mainly composed of sandy soil and boulders. The banks are stable and sparsely vegetated with willow, rose, and ponderosa pine. The stream within this reach is typified by short riffle sections joining numerous pools and flat water areas. During the fall survey, riffle sections averaged 15 to 20 cm in depth. Substrate in the riffle sections was composed of large gravels, cobbles, and boulders, with cobble contributing the greater portion. It was estimated that over 50% of the available fish habitat in this reach is comprised of pools and flat water. During the fall 1980 survey period, seven pools with depths greater than 0.4 m were present. A maximum depth of 1.5 m was recorded in pools at Km 0.7 and Km 1.2.

This section of Champion Creek has moderate potential for rainbow trout spawning (SHSI = 0.47–0.68, Appendix F). The amount of substrate suitable for spawning increased in abundance from isolated small patches in the lower portions of the reach to almost one-half of the wetted channel area in upper portions.

Riparian vegetation providing channel cover consisted mainly of overhanging hawthorn and willow. Channel cover increased from approximately 5% overhang in lower sections of the reach to 90% in upper sections. Submerged trees and logs in the upper section also contributed to the instream channel cover.



LEGEND	
	Pool
	Run
	Riffle
	Cascade
	Falls

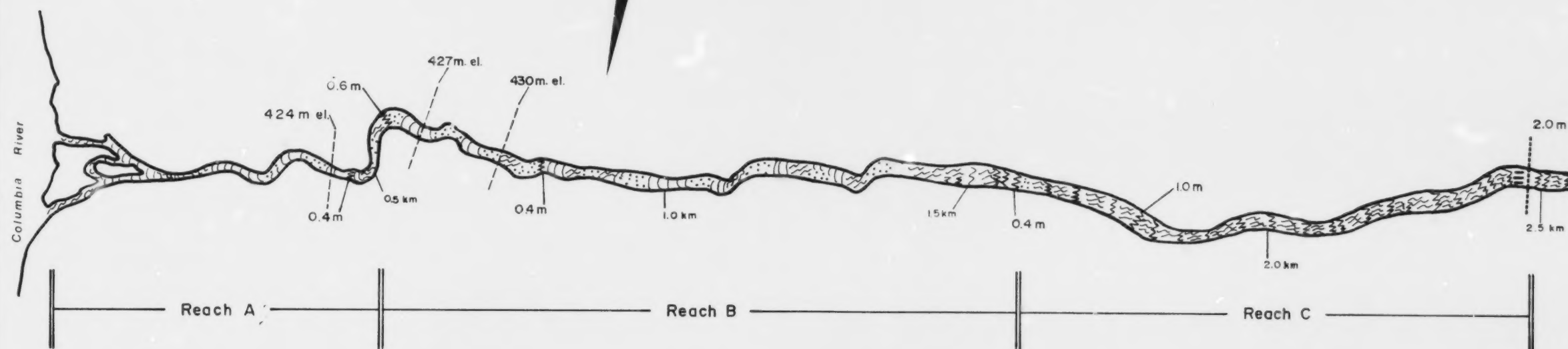
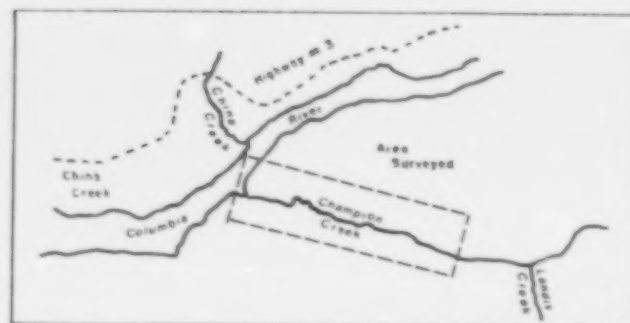


Figure 3.17
 Murphy Creek Fisheries Study
 1980-1981
 Champion Creek
 Flow Types
 R.L. & L. Environmental Services Ltd.



LEGEND	
	Sand
	Cobble
	Sand/Soil/Cobble
	Boulder
	Bedrock
	Vegetation
	Downfall
	Cascade

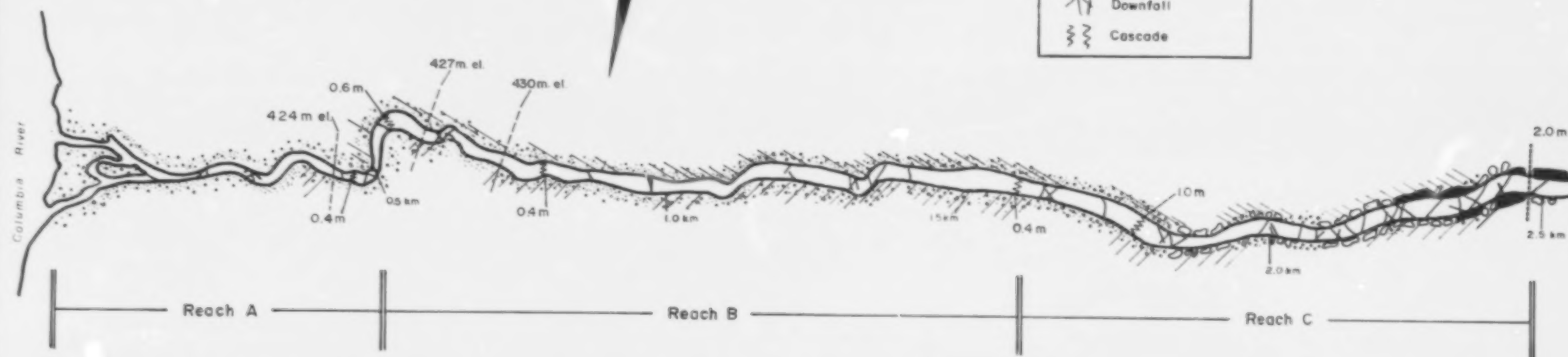
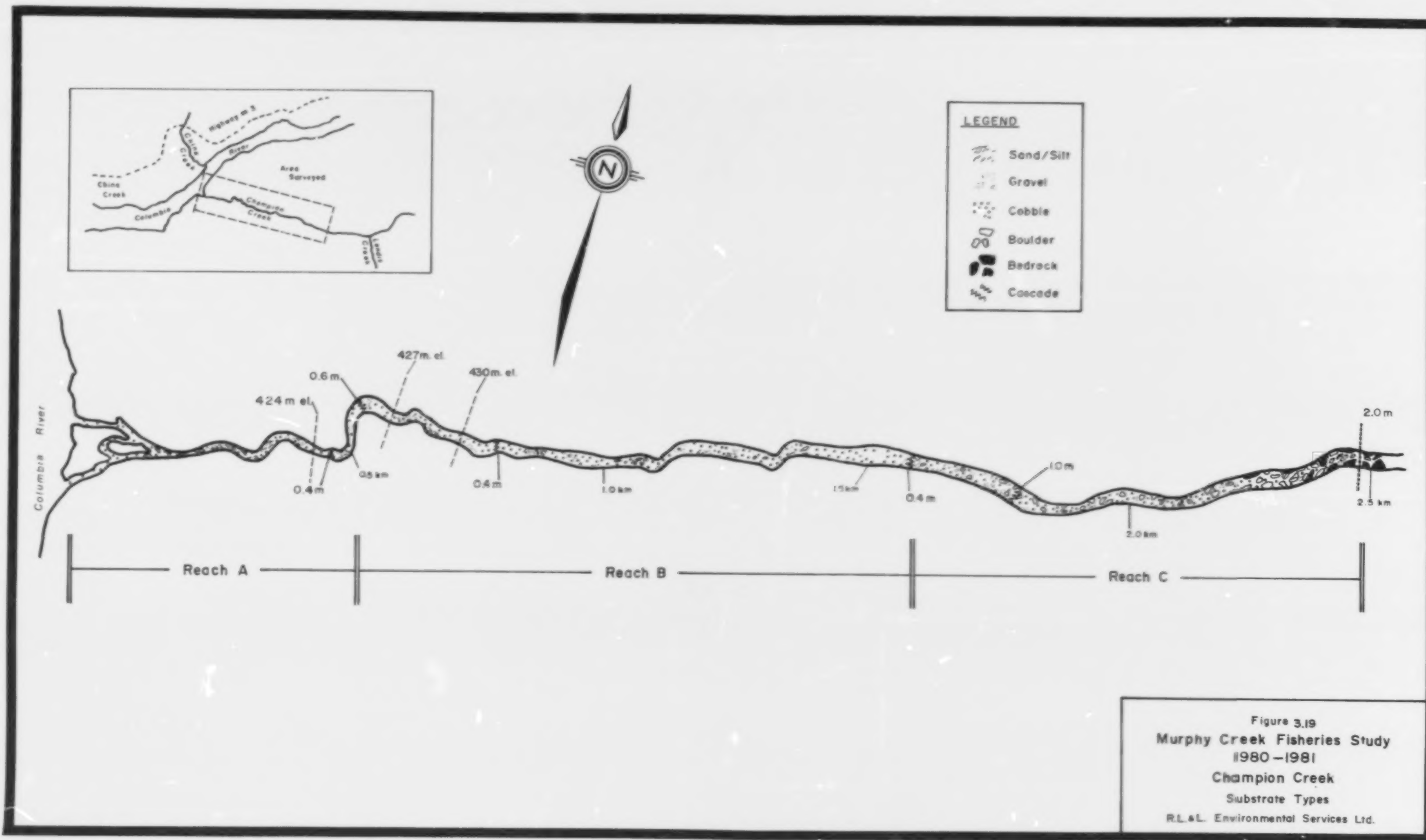


Figure 3.18
Murphy Creek Fisheries Study
1980-1981
Champion Creek
Bank Types
R.L. & L. Environmental Services Ltd.



Reach B exhibited the greatest habitat suitability for rainbow trout spawning and rearing. Suitable substrate, high quality riffle-pool associations, and abundant high quality refugia all contribute to the suitability of this reach for rainbow trout production. Evidence for this assessment was provided by the high concentrations of rainbow trout fry observed during the fall 1980 survey period (Table A.7, Appendix A).

Elevations 427 m and 430 m occur within Reach B. The 130-m section of creek between these two elevations provides limited rainbow trout spawning and rearing potential ($HSI = 0.55$, Appendix F). Available habitat between these contours is characterized by predominant riffle flow type, cobble substrate, and limited cover. One pool, with a maximum depth of 1.5 m, was recorded within this section during the fall of 1980.

Gravel substrate suitable for rainbow trout spawning occurred infrequently in this area, typified by riffle flow over cobble substrates. The low pool abundance within this 200-m section and limited, low quality cover produced a moderately low suitability for rainbow trout rearing.

The majority of Reach B (i.e., 80%) upstream of the 430-m contour (Km 0.77 to Km 1.6) exhibited a greater spawning and rearing potential for rainbow trout ($HSI = 0.75$) than sections downstream of the 430-m contour.

Reach C—Reach C in Champion Creek is a 900-m section extending upstream from Km 1.6 to a 2-m-high waterfall at Km 2.5. The change in gradient near Km 1.6 provides the point of delineation from Reach C. Reach C is characterized by a high gradient (140 m/km), turbulent cascades, a frequently confined channel. Occasional pools (average depth of 0.25 m at low flow) are present. A single large pool (i.e., 15 m^2 , 1.2 m maximum depth) was located at Km 1.8.

Substrate within Reach C primarily consists of boulders and cobble, with only small scattered patches of gravels present on the lee side of boulders, in a few pools, and in backwaters along the banks. Streambanks were composed of boulder, cobble, and organic material although occasional areas of bedrock were present. Banks generally were repose in character.

Riparian vegetation (primarily hemlock associated with a willow/maple understory) provided a high degree of overhanging cover (85% to 90%). Extensive amounts of deadfall and debris were present.

Although cascades and riffle areas were dominant in the lower sections of Reach C, isolated areas of suitable habitat similar to that found in Reach B provided low to moderate rainbow trout spawning and rearing potential. However, the probability of utilization by rainbow trout decreases rapidly in the cascading waters. Young-of-the-year and juvenile rainbow trout were observed in pools as far upstream as Km 2.1; however, these individuals may originate in upper areas (i.e., above falls at Km 2.5) which are reported to contain rainbow trout (B. Salekin, pers. comm.). In addition, Champion Lakes are routinely stocked with this species (H. Andrusak, pers. comm.).

3.6.3.3 Blueberry Creek

Blueberry Creek drains an area of 14 700 ha (Water Survey of Canada 1980). It arises in a well-forested marsh area of the Monashee Mountains and drains into Nancy Greene Lake. Upon exiting the lake, Blueberry Creek flows through a wide valley for 13 km, finally descending into a steeper valley to the Columbia River. The length of the creek is approximately 30 km, with the only named tributary being Judkin Creek at Km 4.6. Between Km 6.8 and Nancy Greene Lake 17 unnamed tributaries enter Blueberry Creek.

(a) Gradient

The gradient profile of Blueberry Creek is illustrated in Figure 3.20. The lower 1.1 km of the creek has a gradient of approximately 33 m/km. Between Km 1.1 and Km 2.0 the gradient is considerably lower, averaging 14 m/km. Upstream of Km 2.0, the gradient again rises sharply, averaging 53 m/km in a 0.6-km section.

(b) Discharge

The discharge in Blueberry Creek was estimated to be approximately $1 \text{ m}^3/\text{s}$ on 9 September 1980. During low flow periods, the shallow water depths over the large gravel and cobble fan at the confluence of Blueberry

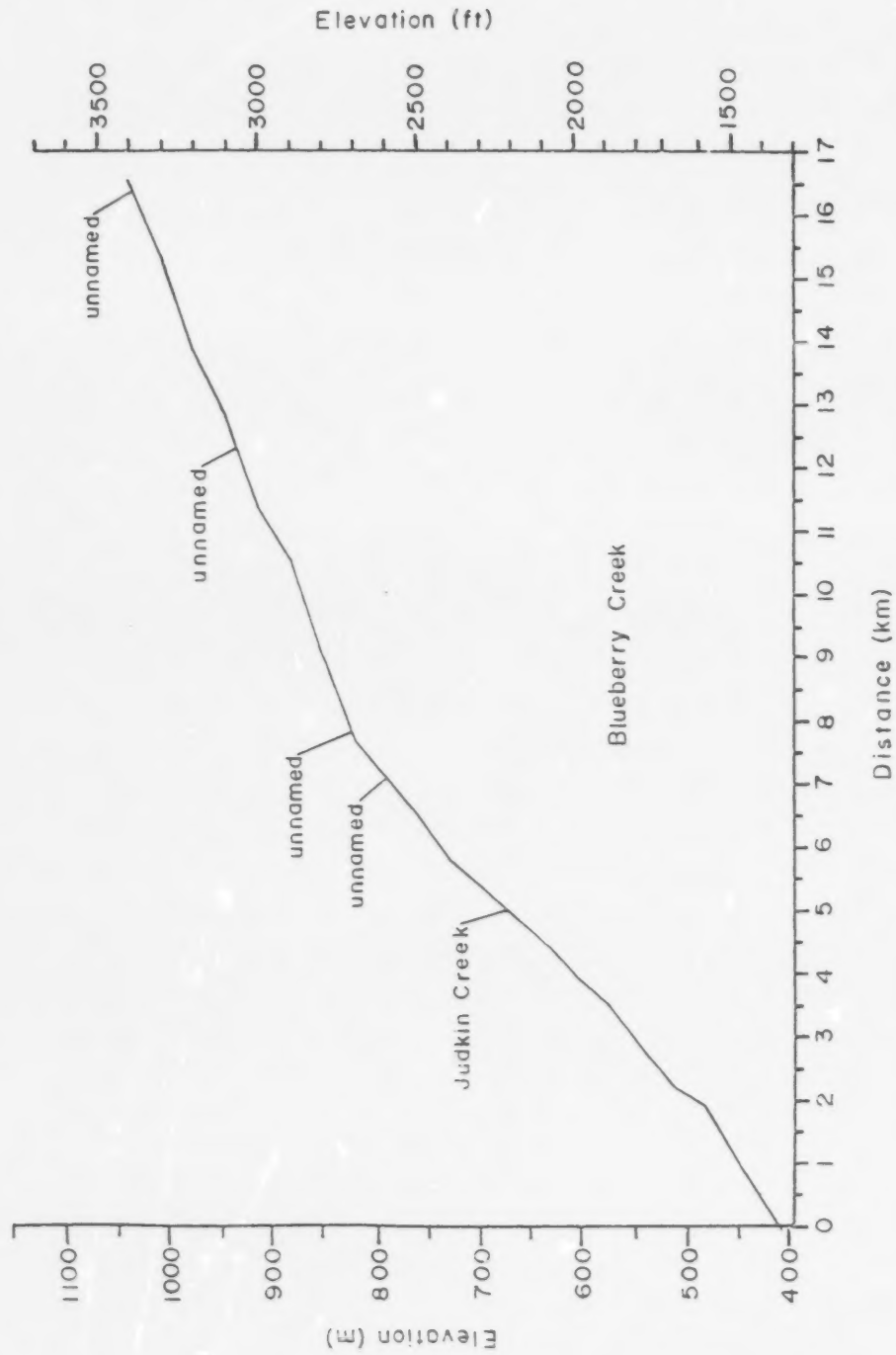


Figure 3.20. Gradient profile of Blueberry Creek.

Creek may limit fish movement into the stream. This especially would be a problem when water levels in the Columbia River are low. Blueberry Creek also is subject to high discharge occurrences during spring freshets. These periods of high flow also may inhibit upstream movements of fish, and limit the spawning and rearing suitability of the creek for rainbow trout.

(c) Water Temperatures

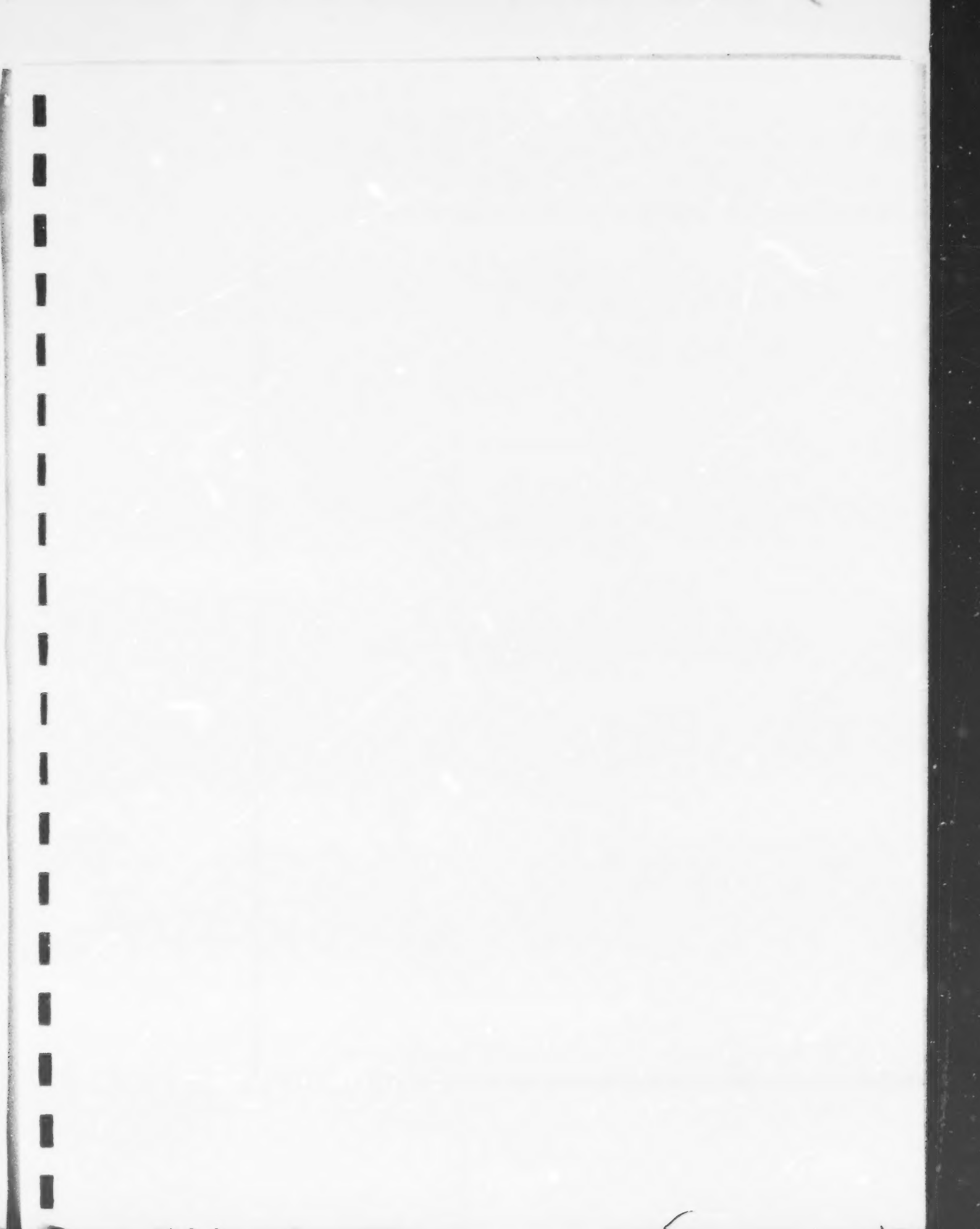
Seasonal temperature variation in Blueberry Creek was comparable to that of similar creeks in the study area (i.e., Murphy Creek and China Creek). The maximum temperature recorded during the studies was 14°C on 17 July 1980.

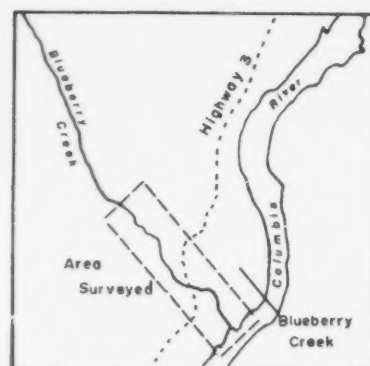
(d) Reach Description

The predominant flow types, bank types, and substrate for the sections of Blueberry Creek surveyed are illustrated in Figures 3.21, 3.22, and 3.23, respectively.

Reach A—This section is 890 m long, extending from the confluence to a 0.3-m-high cascade near the old highway crossing. It is characterized by riffles or runs interrupted by exposed boulders. Four major pools were present in the upper regions of this reach during the fall survey—one at Km 0.7 (4 m x 8 m, maximum depth 1.2 m) and the second 70 m farther upstream (8 m x 15 m, maximum depth 1.5 m). The third pool (10 m x 8 m, maximum depth 1 m) and the fourth pool (12 m x 9 m, maximum depth 1 m) were located an additional 90 m upstream (Km 0.86). These two pools were separated by a 1.0-m vertical drop, the downstream limit of the lower pool being delineated by a 0.4-m cascade and the upper limit of the top pool being a 0.3-m-high cascade. Rainbow trout fry were observed in each of these pools.

The immediate streambanks were composed of primarily cobble and boulders. They averaged 1.4 m in height and frequently were undercut. One exposed sand bank (8 to 10 m high, 40 m long) was present approximately 250 m upstream of the confluence. Overhanging riparian vegetation provided cover of approximately 40% of the wetted channel. Extensive amounts of deadfall and debris contributed to abundant instream cover habitat.





LEGEND	
	Pool
	Run
	Riffle
	Cascade

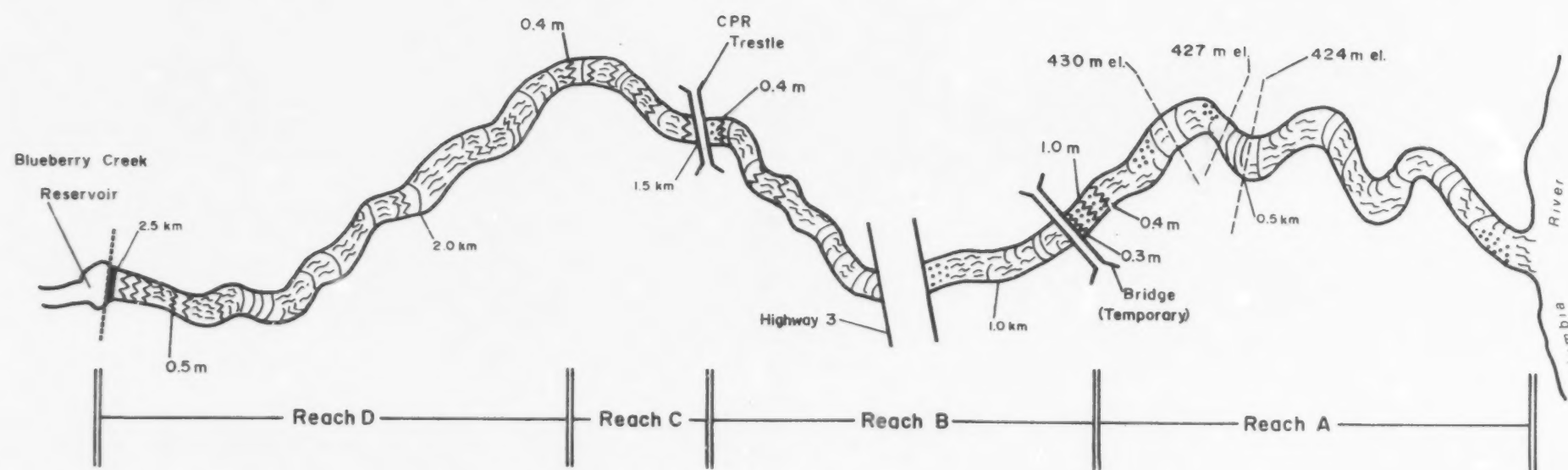
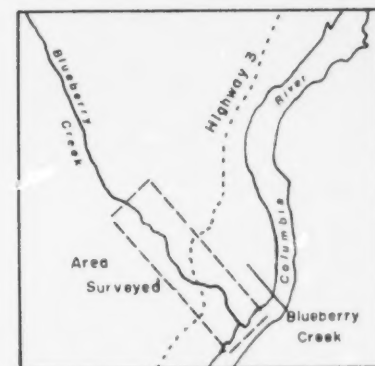


Figure 3.21
 Murphy Creek Fisheries Study
 1980-1981
 Blueberry Creek
 Flow Types
 R.L. & L. Environmental Services Ltd.



LEGEND	
	Sand
	Cobble
	Sand/Soil/Cobble
	Boulder
	Bedrock
	Vegetation
	Downfall
	Cascade

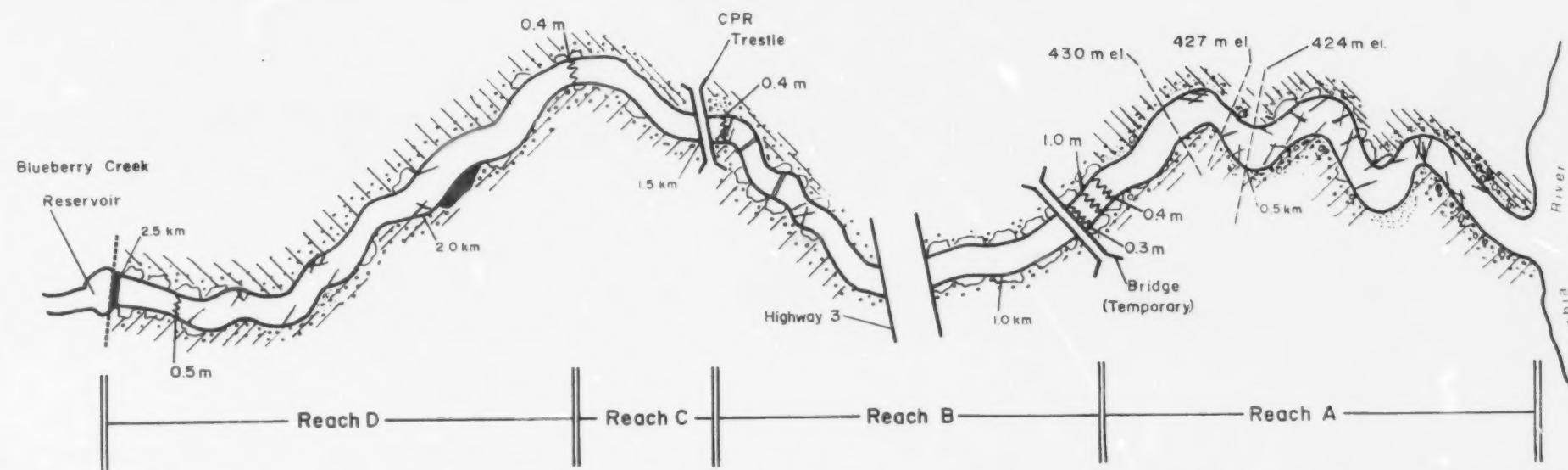
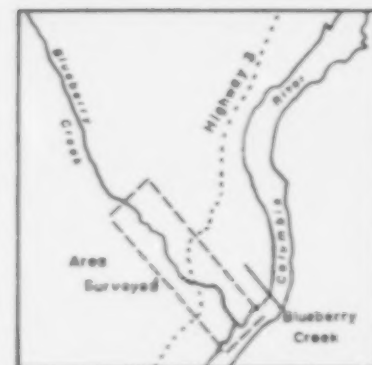


Figure 3.22
 Murphy Creek Fisheries Study
 1980-1981
 Blueberry Creek
 Bank Types
 R.L. & L. Environmental Services Ltd.



LEGEND	
	Sand
	Gravel
	Cobble
	Boulder
	Bedrock
	Cascade

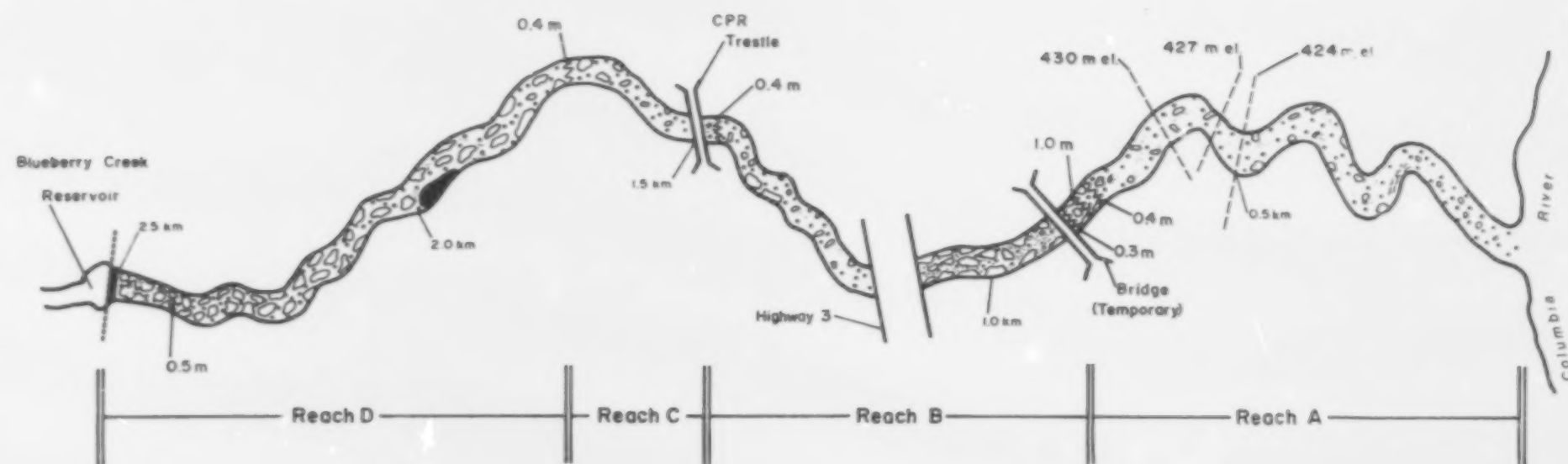


Figure 3.23
 Murphy Creek Fisheries Study
 1980-1981
 Blueberry Creek
 Substrate Types
 R.L. & L. Environmental Services Ltd.



The substrate within this reach was primarily cobble with numerous boulders present. Gravel patches occurred with greatest frequency 600 to 870 m above the confluence.

Elevations 424 m, 427 m, and 430 m occur in this reach in the region 500 to 650 m upstream of the mouth. The section between the 424-m and 427-m elevations had low spawning suitability for rainbow trout (SHSI = 0.30, Appendix F). The 90-m section between the 427-m and 430-m contours included part of the best salmonid spawning habitat observed in the creek (SHSI = 0.7, Appendix F). Also, good rearing potential is provided by ample cover in slow flow areas.

Reach B—This is a 610-m section of creek from the 0.3-m-high weir (Km 0.89) to a cement trestle at Km 1.5. This reach is typified by a predominant riffle flow interrupted by emergent boulders. One major pool was present (12 m x 6 m, maximum depth = 4.0 m) created by a weir (Km 1.4).

The immediate streambanks averaged approximately 1.2 m in height although the lower section of the reach had 1.5 to 3.0-m-high banks. They were composed of mainly cobble and boulders with undercutting common in the upper areas. Riparian overhang varied from approximately 20% coverage in the upper section to zero coverage in the lower two-thirds of the reach. Very little debris or deadfall was present. Gravels represented only a small amount of the substrate present.

A 0.4-m vertical drop occurred at the culvert beneath the highway (Km 1.1). This, together with high water velocity through the culvert, likely prevents upstream movement of fish. At Km 1.4, there is a 1.0-m drop at the exit of the culvert beneath the train trestle.

Due to the large substrate size, limited pool habitat, and low amount of instream cover, Reach B exhibited low potential for rainbow trout spawning and only moderate potential for rearing.

Reach C—This reach extends for a 200-m section of Blueberry Creek, from the upstream end of the train trestle to a 0.4-m drop preceding a cascade (approximately Km 1.7). It is typified by riffles and runs interrupted by exposed cobble and boulders. Depths generally were less than 0.3 m.

The immediate streambanks generally were composed of boulders and cobble, and averaged 1.9 m in height. They primarily were scoured with some undercutting. Riparian overhang averaged 33% of the wetted channel, the maximum being 50% in the mid-section.

The substrate was primarily cobble with a few scattered boulders. A few scattered areas of gravel substrate were present.

Reach D—Reach D extends from the 0.4-m cascade (Km 1.7) to a cement weir at Km 2.5. This reach is typified by moderate riffles and cascades in a restricted channel. There were no major pools observed within this reach; however, there were extensive backeddy areas up to 3.0 m long and 1.5 m deep occurring below large boulders.

The immediate streambanks were composed of primarily boulders and cobble and generally were undercut; they averaged 2.0 m in height. Overhanging riparian vegetation, primarily cedar and willow, covered approximately 56% of the wetted width with a maximum of 70% occurring in two areas of the reach.

In the upper 400-m section of this reach, the creek flows through a series of steep cascades over large boulders. A 2.0-m-high waterfall divided by one large boulder occurs 180 m into the initial steep cascade. The pool at the waterfall base was 2.0 m x 0.6 m, and 0.5 m deep. A 2.0-m-high cement weir is located approximately at Km 2.5, the upstream limit of Reach D. This structure forms a reservoir for the community of Blueberry Creek.

Reach D exhibits low to moderate potential for rainbow trout spawning (SHSI = 0.5, Appendix F), with scattered patches of suitable spawning gravel. The upper section (i.e., steep cascade area) was an exception, with small patches of gravels in turbulent backeddies. This reach exhibited moderate rearing potential with abundant cover for fry and juveniles; however, large freshets (evident in bank scouring) may reduce the potential (RHSI = 0.6, Appendix F).

3.6.3.4 China Creek

China Creek is approximately 11 km long, entering the Columbia River from the west at Km 33.1 just upstream of the settlements of Genelle and China Creek. It drains a 2850-ha area of the Monashee Mountains, including a logged region in its headwaters. Three unnamed tributaries enter China Creek at Km 4.0, 6.0, and 9.2. There are no lakes within the drainage.

The upper sections of the creek flow through a restricted channel of large boulders and bedrock. In the lower sections, the substrate is primarily cobble; the channel is characterized by an irregular meander pattern. Occasional braiding of the channel occurs in the lower sections.

(a) Gradient

The gradient profile of China Creek is illustrated in Figure 3.24. In the 1.1-km section of China Creek below the highway crossing, the gradient averages approximately 38 m/km; however, upstream of the highway, the gradient is much steeper, averaging 113 m/km over a 6-km section.

(b) Discharge

Discharge was observed to be less in the lower section than farther upstream ($0.04 \text{ m}^3/\text{s}$ versus $0.1 \text{ m}^3/\text{s}$) on 10 September 1980. This may be a result of water dissipating into cobble substrate. The shallow water depth over the large gravel and cobble fan likely limits accessibility to the creek during low flow periods by fish from the Columbia River. China Creek is subject to high discharge periods during spring freshets. These periods of high flow may limit the spawning and rearing suitability of the creek for rainbow trout.

(c) Temperatures

The maximum temperature recorded in China Creek during this study was 15°C on 17 July 1980. The majority of the creek receives extensive shading as a result of overhanging vegetation.

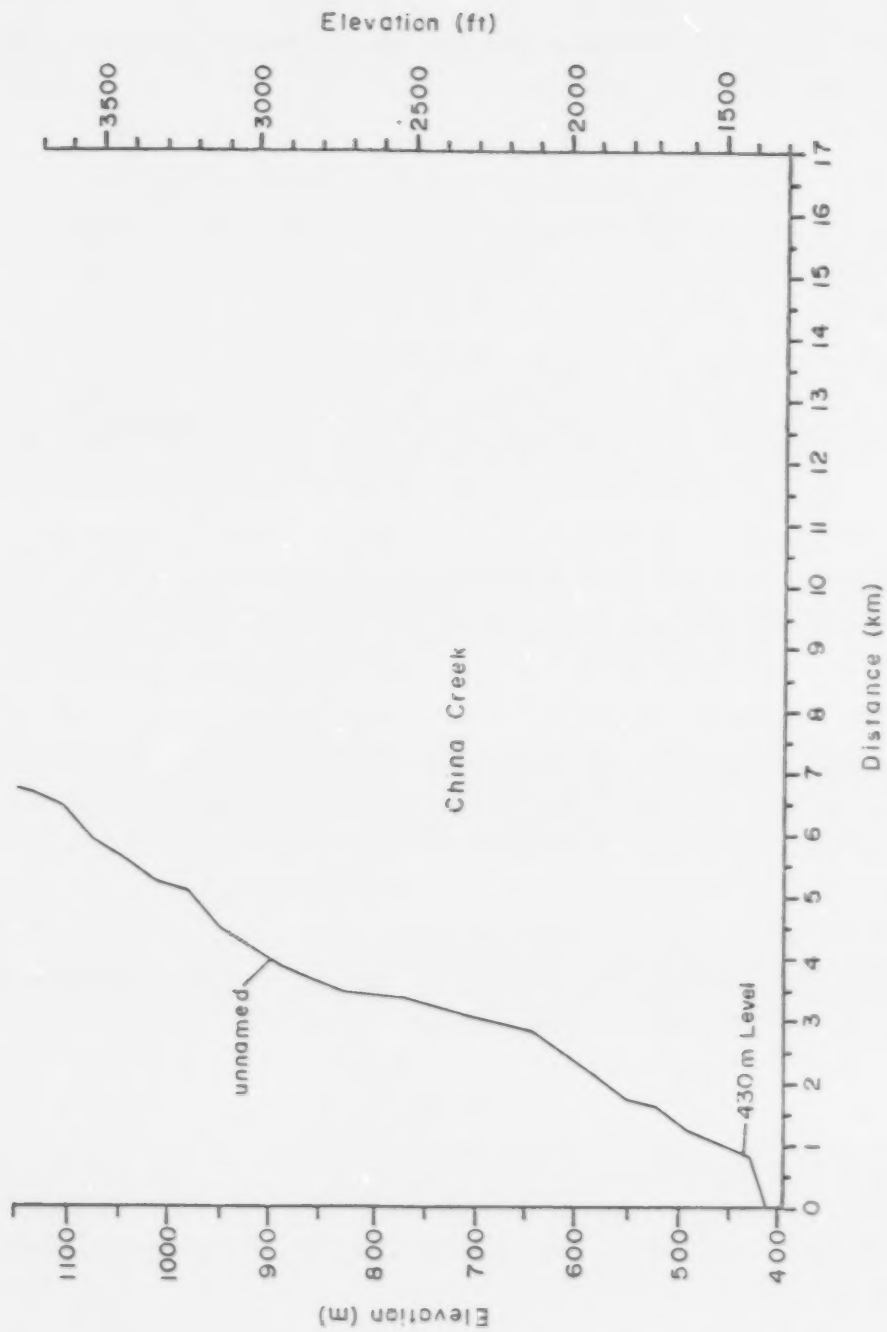


Figure 3.24. Gradient profile of China Creek.

(d) Reach Description

The predominant flow types, bank types, and substrate for the sections of China Creek surveyed are illustrated in Figures 3.25, 3.26, and 3.27, respectively.

Reach A—Reach A extends from the confluence with the Columbia River to a 1.2-m-high cascade, a distance of approximately 0.5 km. No major pools occurred within this section during the fall survey, but backeddies were frequent. Depth averaged less than 10 cm, and mid-channel velocity generally was less than 40 cm/s. Wetted width generally was less than 1 m at the time of the fall survey.

The immediate streambanks were composed of primarily soil and boulders. Large sections of the banks were slumping. Three high, exposed sand banks were noted along the north bank at Km 0.05, 0.14, and 0.32. Overhanging riparian vegetation, primarily composed of willow, pine, and poplar, provided approximately 25% coverage of the wetted channel. Dead-fall and debris were abundant.

The creek bed was composed of mainly cobble and boulders; however, scattered areas of gravel substrate occurred, with the highest amounts present in the mid-sections of the reach. These areas exhibit the best potential for rainbow trout spawning within the observed section of China Creek. Rearing potential for rainbow trout is moderate ($RHSI = 0.67$, Appendix F), with the low number of pools and low fall discharge being limiting.

The 424-m, 427-m, and 430-m contour levels all occur within this reach. The best rainbow trout spawning and rearing habitat extends from approximately 80 m below the 424-m level to 40 m above it (just below the 427-m level). The riparian overhang and channel debris contribute to good rearing habitat in this section. The section from the 427-m to the 430-m elevation has moderate to good rearing potential but low spawning potential as a result of only isolated patches of gravel. At the mouth of the creek a steep gradient and waterflow through boulders could prevent upstream passage of fish, especially during low water periods in the mainstem Columbia River.

Reach B—This reach extends from Km 0.5 to Km 1.7. The predominant flow types in this section are cascades and riffles flowing over boulder and bedrock outcroppings. Only small, widely separated gravel patches occurred. Average velocity and depth at the time of the fall survey were 0.4 m/s and 0.2 m, respectively.

The immediate streambanks, averaging 1.4 m in height, were composed of primarily cobble and boulder; considerable slumping was evident. Extensive shading and instream cover was provided by a dense riparian overhang, scattered debris, and deadfall. Areas of exception to this were where the railroad, highway, and seismic line crossed the creek.

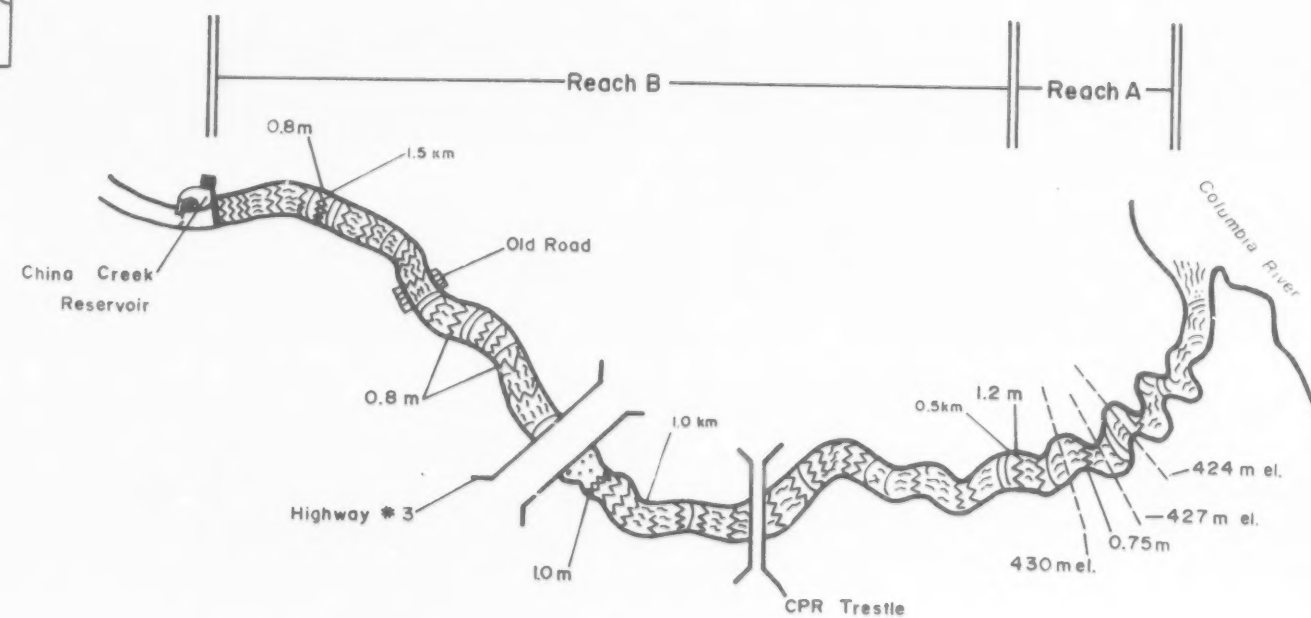
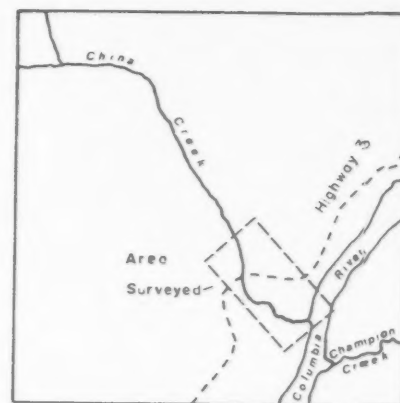
Reach B exhibits low potential for rainbow trout spawning and rearing (i.e., HSI = 0.30, Appendix F). Factors limiting the suitability include steep gradient and large substrate size.

Reach B contains five obstructions to upstream fish movement. The first impasse, located at Km 1.1, is an old weir (1.0 m in height) constructed of logs and boulders. There are no pools along the downstream edge of the weir to assist fish passage. The second obstruction is the highway culvert located 25 m upstream of the weir. It is unlikely that any fish can pass upstream through the culvert (due to velocity barrier and drop at outlet), especially during the spring high flow periods. The third probable barrier is a log weir at Km 1.5. This structure resulted in a vertical drop of 2.3 m into a 6 m x 3 m pool at the time of the survey (fall 1980). Approximately 60 m upstream of the weir is a 10-m-high cascade through a 40-m-long section of large boulders. At the upstream limit of Reach B (Km 1.7), a 0.4-m-high stone and steel weir (associated with the water supply of the settlements of China Creek and Genelle) spans the creek.

3.6.3.5 Murphy Creek

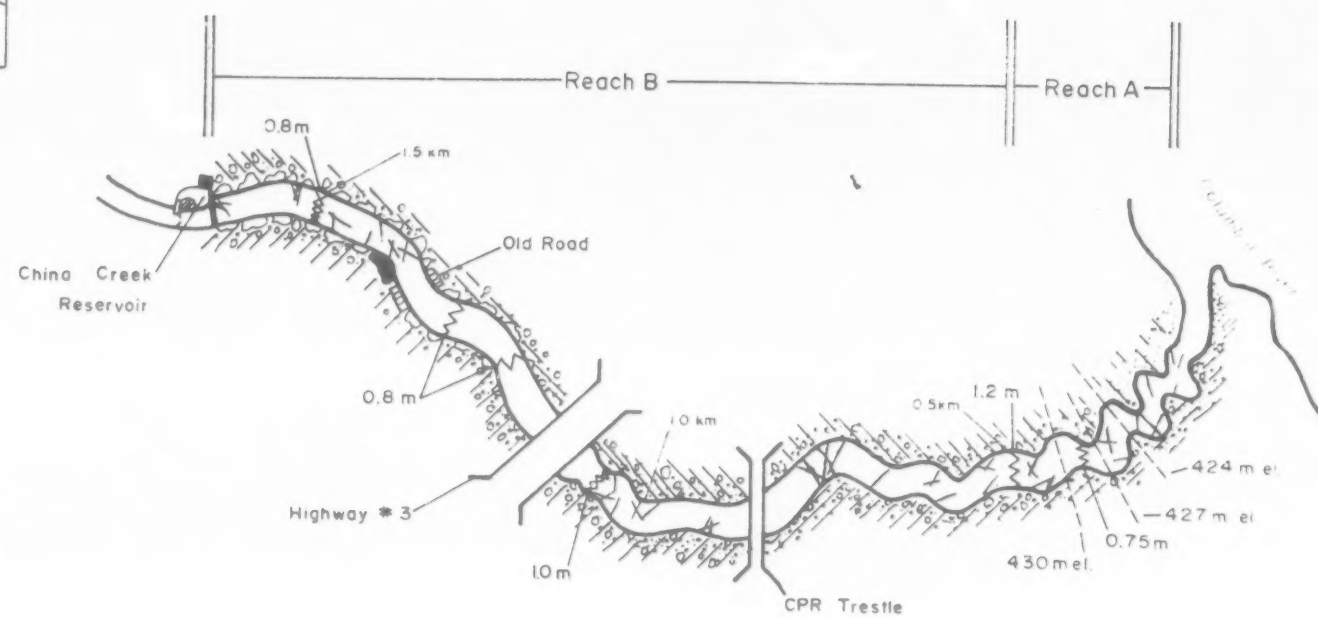
Murphy Creek flows in an easterly direction from the Monashee Mountains, entering the Columbia River at Km 24.3 (Figure 2.1). There are five main tributaries entering in the 10.4-km length of Murphy Creek. The two named tributaries, Neptune and Elgood creeks, enter Murphy Creek at Km 6.0 and Km 11.5, respectively. The three unnamed creeks enter at Km 4.8, Km 7.4, and Km 8.7.





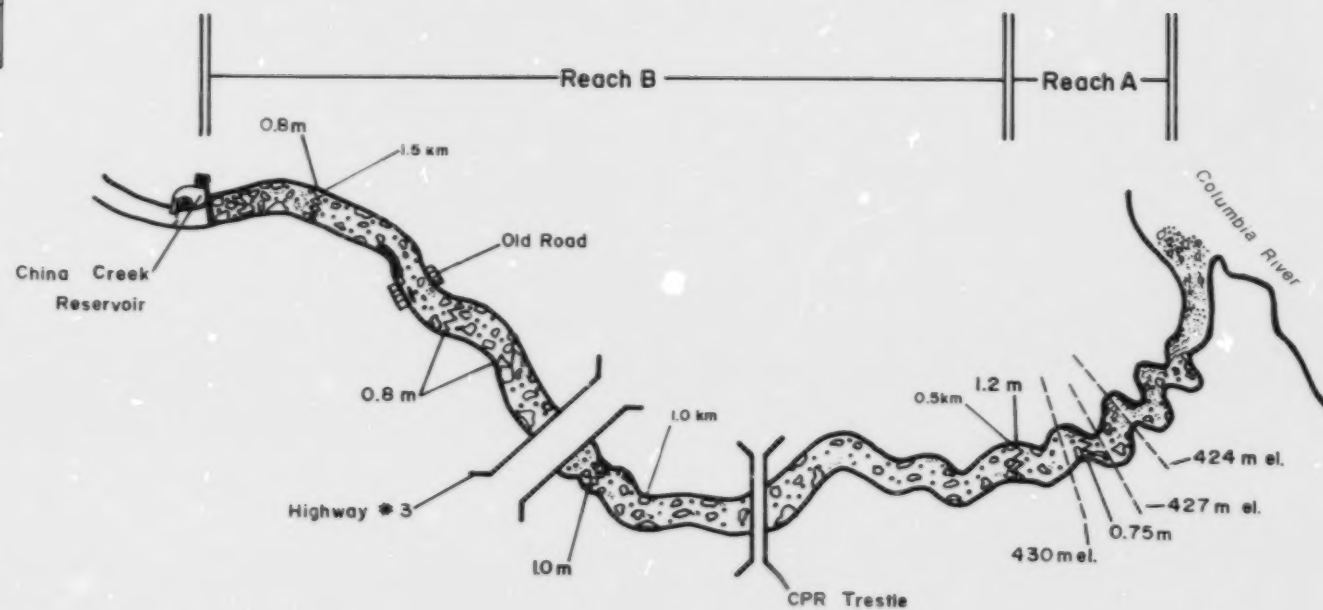
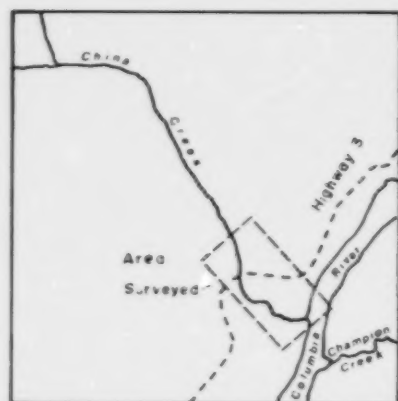
LEGEND	
	Pool
	Run
	Riffle
	Cascade
	Log Weir

Figure 3.25
 Murphy Creek Fisheries Study
 1980-1981
 China Creek
 Flow Types
 R.L. & L. Environmental Services Ltd.



LEGEND	
(Dotted pattern)	Sand
(Dotted pattern with larger dots)	Cobble
(Dotted pattern with even larger dots)	Sand/Soil/Cobble
(Large circle with dot)	Boulder
(Solid black shape)	Bedrock
(Hatched pattern)	Vegetation
(Star symbol)	Downfall
(Wavy line)	Cascade
(X symbol)	Log Weir

Figure 3.26
 Murphy Creek Fisheries Study
 1980-1981
 China Creek
 Bank Types
 R.L. & L. Environmental Services Ltd



LEGEND	
	Sand
	Gravel
	Cobble
	Boulder
	Bedrock
	Cascade
	Log Weir

Figure 3.27
 Murphy Creek Fisheries Study
 1980-1981
 China Creek
 Substrate Types
 R.L. & L. Environmental Services Ltd.

(a) Gradient

The gradient profile of Murphy Creek is illustrated in Figure 3.28. The average gradient in the lower 0.6 km (i.e., length accessible to fish) is approximately 80 m/km, the highest of all the major tributaries in the study area (Figure 3.12). This steep gradient results in turbulent flow consisting of cascades, plunge pools, and swirling backeddies. The lower 0.2 km exhibit a moderate gradient of 20 m/km. The gradient increases thereafter and remains high.

(b) Discharge

The discharge in Murphy Creek was estimated to be approximately $0.7 \text{ m}^3/\text{s}$ on 8 September 1980. During low flow periods, shallow water depth over the cobble and small boulder fan at the confluence of Murphy Creek may inhibit fish movement into the stream, especially during periods when the water levels are low in the Columbia River (i.e., very steep gradient over cobble boulder substrate in the lower 25 to 50 m of the stream). Murphy Creek is subject to very high flows during spring freshets. These periods of high flow also may inhibit upstream movement of fish into the creek.

(c) Water Temperatures

The maximum water temperature recorded in Murphy Creek during the present study was 14°C on 17 July 1980. The minimum temperature recorded was 0°C on 6 February 1981. Extensive cover (i.e., crown and overhang) results in small daily temperature variations.

(d) Reach Description

The predominant flow types, bank types, and substrate for the lower sections of Murphy Creek are illustrated in Figures 3.29, 3.30, and 3.31, respectively.

Reach A—Reach A extends from the confluence to the highway culvert at Km 0.6. It appears that this culvert (approximately 5 m in diameter and 40 m in length) constitutes an impasse to the upstream movement of fish in

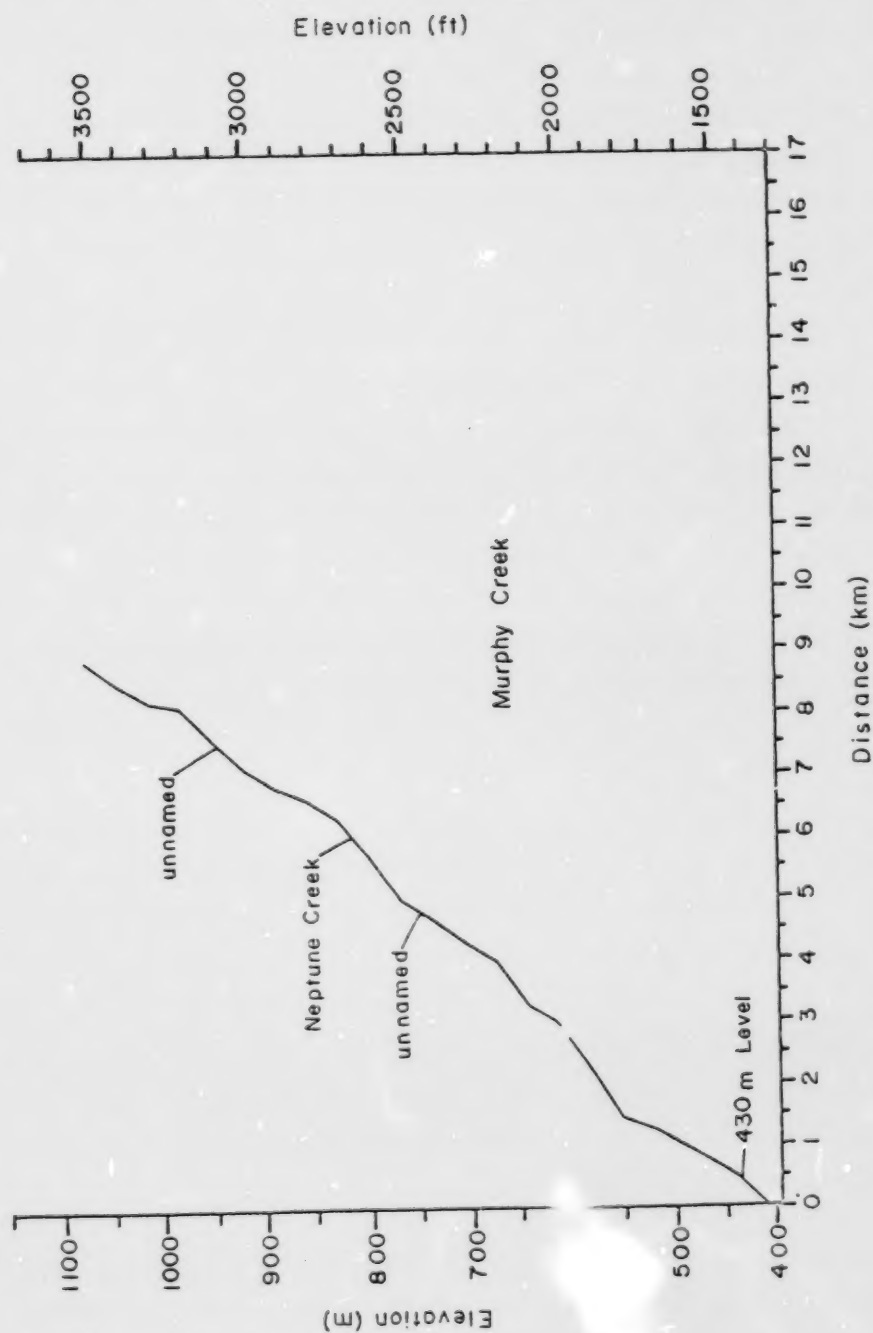
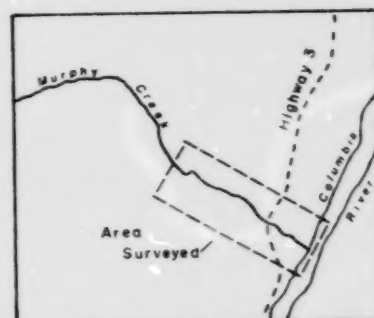


Figure 3.28. Gradient profile of Murphy Creek.



LEGEND	
	Pool
	Run
	Riffle
	Cascade
	Log Weir

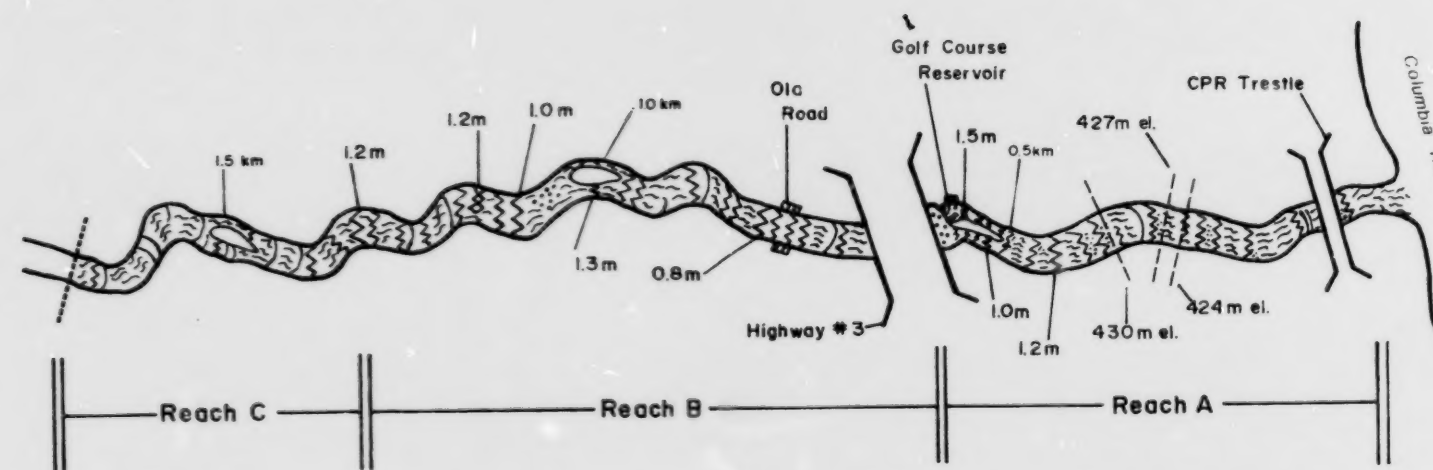
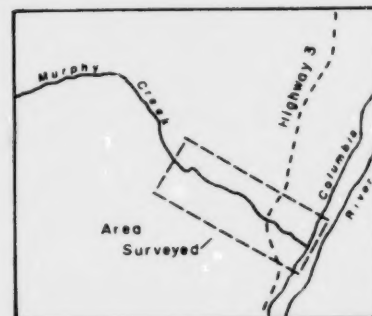


Figure 3.29
 Murphy Creek Fisheries Study
 1980-1981
 Murphy Creek
 Flow Types
 R.L. & L. Environmental Services Ltd.



LEGEND	
	Cobble
	Sand/Soil/Cobble
	Boulder
	Bedrock
	Vegetation
	Downfall
	Cascade
	Log Weir

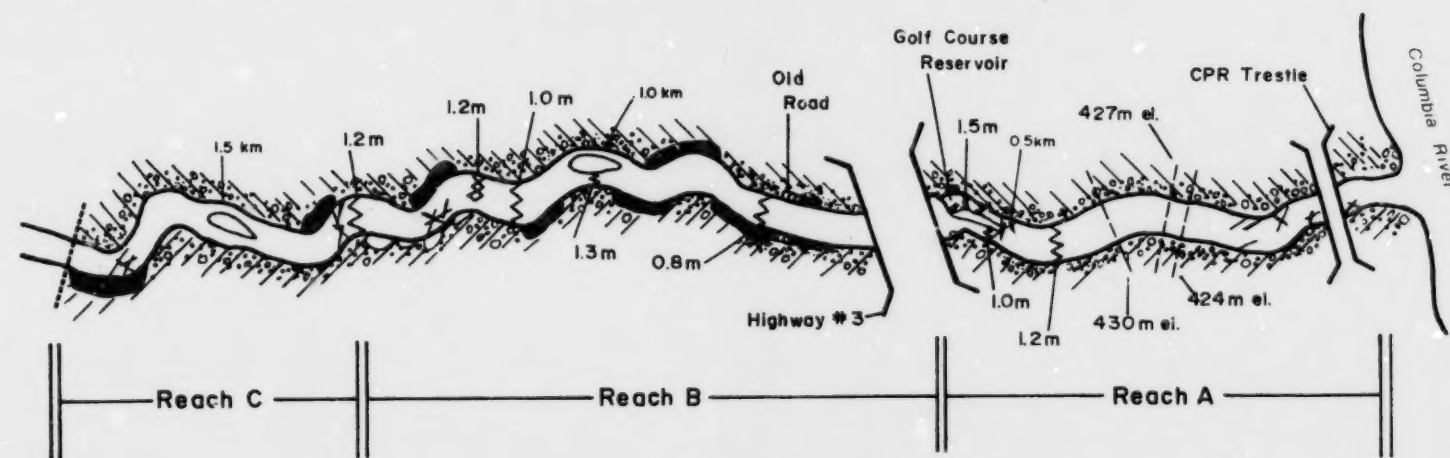
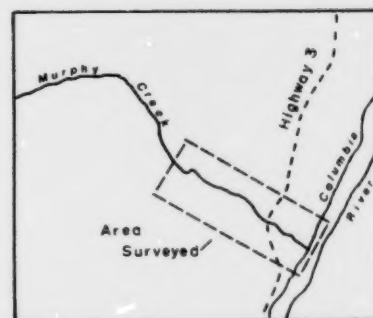


Figure 3.30
 Murphy Creek Fisheries Study
 1980-1981
 Murphy Creek
 Bank Types
 R.L. & L. Environmental Services Ltd.



LEGEND	
	Gravel
	Cobble
	Boulder
	Bedrock
	Cascade
	Log Weir

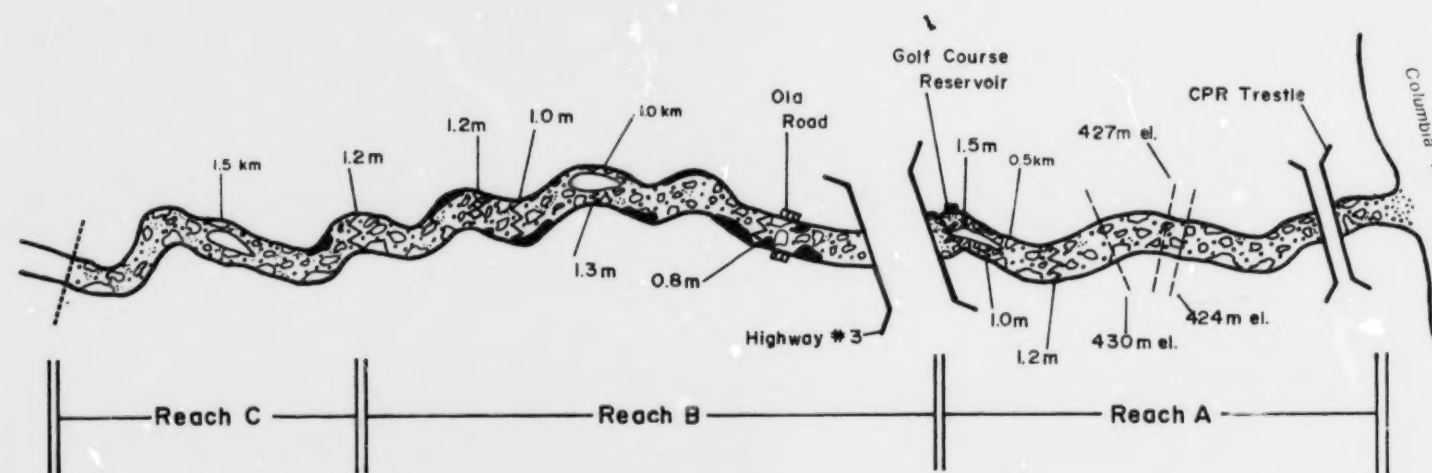


Figure 3.31
 Murphy Creek Fisheries Study
 1980-1981
 Murphy Creek
 Substrate Types
 R.L. & L. Environmental Services Ltd.

the creek. Within this reach, Murphy Creek is characterized by series of cascades, small pools, and riffles. During the fall survey, stream depth averaged about 0.3 m. The immediate streambanks in this reach were composed of primarily till (60% cobble and boulder) and organic material. A small section of bedrock occurred at Km 0.2. Areas of slumping and undercutting were occasionally present. At Km 0.1, the banks near the railway trestle were stabilized with large boulders producing a stable, confined channel. Bank heights averaged 1 to 4 m. Riparian vegetation, consisting of mainly cottonwood, alder, and willow, provided extensive crown cover. Channel overhang averaged 75% for this reach.

The substrate within Reach A was composed of primarily cobble and boulders (up to 150 cm in diameter). These large boulders created suitable rearing habitat in the form of backeddies and submerged cover. Substrate suitable for rainbow trout spawning consisted of isolated small patches of gravels; however, suitable areas were extremely limited in number. Two pools with a maximum depth of 2 m occurred in this reach, one at Km 0.55 and one at Km 0.58. The latter constitutes a plunge pool; water flowing out of the highway culvert causes turbulence and swirling. The pool at Km 0.55 is an artificially created reservoir (used for water supply by the adjacent golf course). Three kokanee and approximately 80 juvenile rainbow trout were observed in the reservoir on 8 September 1980.

Elevations 424 m, 427 m, and 430 m all occur within approximately an 80-m length (i.e., Km 0.29 to Km 0.37) of Reach A. Salmonid spawning potential below these elevations is low (SHSI = 0.23, Appendix F), primarily due to the paucity of suitable substrate. Occasional pools and an abundance of submerged refugia result in a moderate rearing potential below these elevations (RHSI = 0.50, Appendix F).

Reach B—Reach B extends from the highway culvert at Km 0.6 to a 1.2-m-high cascade at approximately Km 1.3. This section is characterized by cascade and riffle flow through a stable, well-confined channel. There were no pools noted during the fall survey; however, backeddies formed by boulders and bedrock outcroppings were abundant. The immediate stream-

banks (1.7-m average height) were composed of glacial till and organic material. There also were occasional areas of bedrock. Banks generally were stable, although undercutting was noted infrequently. Riparian vegetation (mainly cedar, cottonwood, and willow) distributed along 95% of the bank, provided crown cover for about 60% of the channel. Channel debris (i.e., tree branches) was present in moderate quantities during the 1980 fall survey period.

The substrate consisted of primarily cobble and boulders. Isolated areas of small to medium-sized gravel were present on the lee side of boulders.

Reach B exhibits low spawning potential for kokanee or rainbow trout (SHSI = 0.30, Appendix F), mainly due to the paucity of suitable substrate. Rearing potential is moderate (RHSI = 0.70, Appendix F) due to the presence of suitable cover.

Reach C—A change in stream gradient and general flow character near Km 1.3 mark the beginning of Reach C. The flow characteristics of this section are typified by moderate riffles with short runs and frequent backeddies among large boulders. Although the creek flows in a relatively stable, well-defined channel throughout most of the reach, side channels and undercut banks are present in some areas. The immediate banks (average - 1.0 m in height) are composed of glacial till (about 60% large cobble and boulder) and organic material. Bedrock outcroppings occur in a few areas. Dense riparian vegetation, distributed along 80% of the bank, provides constant shading to the majority of this reach. Deadfall and debris provide occasional instream cover. The substrate is composed of primarily boulders and cobble. Areas of gravel substrate were located in occasional runs.

This reach has the highest potential for rainbow trout spawning and rearing (HSI = 0.60, Appendix F) of the areas surveyed in Murphy Creek. Flow character, the presence of suitable gravel areas, and substantial cover create a moderately suitable environment for salmonid production. Electro-fishing in this reach documented the presence of what appears to be a slow-growing resident population of rainbow trout. As mentioned previously, it is thought that the upstream limit of fish movement from the Columbia River is the highway culvert at Km 0.6.

3.6.3.6 Minor Tributaries

Four minor tributaries within the study area were examined also. They are Rialto, Jordan, Sullivan, and Billy creeks, which enter the Columbia River at Km 55.0, Km 32.0, Km 28.1, and Km 22.0 respectively. Due to the intermittent nature of these creeks, they were not considered as having major influences on the fisheries resource for the Columbia River; consequently, a detailed habitat assessment was not conducted.

3.7 RESOURCE USE

This section describes the extent of fishing, the angling success, and the relative importance of various species to the sport fishery within the study area. The information used was obtained mainly from B.C. Fish and Wildlife Branch creel surveys (1976, 1980, 1981) and from personal communication with local anglers. The recreational fishery also is described in detail in the Murphy Creek Project Recreation and Tourism Report prepared by Edwin, Reid, and Associates Ltd. (Stephenson 1981).

Although commercial fishing is not carried out within the study area, recreational fishing activity is extensive. Most angling occurs in the first 6 to 7 km below the Hugh Keenleyside Dam (B.C. Fish and Wildlife Branch 1981; see Appendix H). The major angling areas between Trail and the Hugh Keenleyside Dam, as provided by Edwin, Reid, and Associates Ltd., are shown in Figure 3.32 and described in Table 3.27 (J. Stephenson, pers. comm.). It was estimated that two large and 50 smaller fishing sites occur in the mainstem Columbia River upstream of the proposed damsites (primarily in 12 major angling areas at various eddies and creek mouths), while one large and five smaller sites occur downstream of the site (Stephenson 1981). R. DeBiasio (pers. comm.), however, has indicated that numerous angling areas (at least 22) exist below Trail. These areas are fished mainly from the banks, using primarily bait or flies.

The total angler use within the study area is estimated as 13 940 angler days (B.C. Fish and Wildlife Branch 1981). This figure is derived from census data for 8 months (March to October) and an assumed level of effort for the remaining 4 months, and represents a total estimated annual effort of 20 083 rod hours.

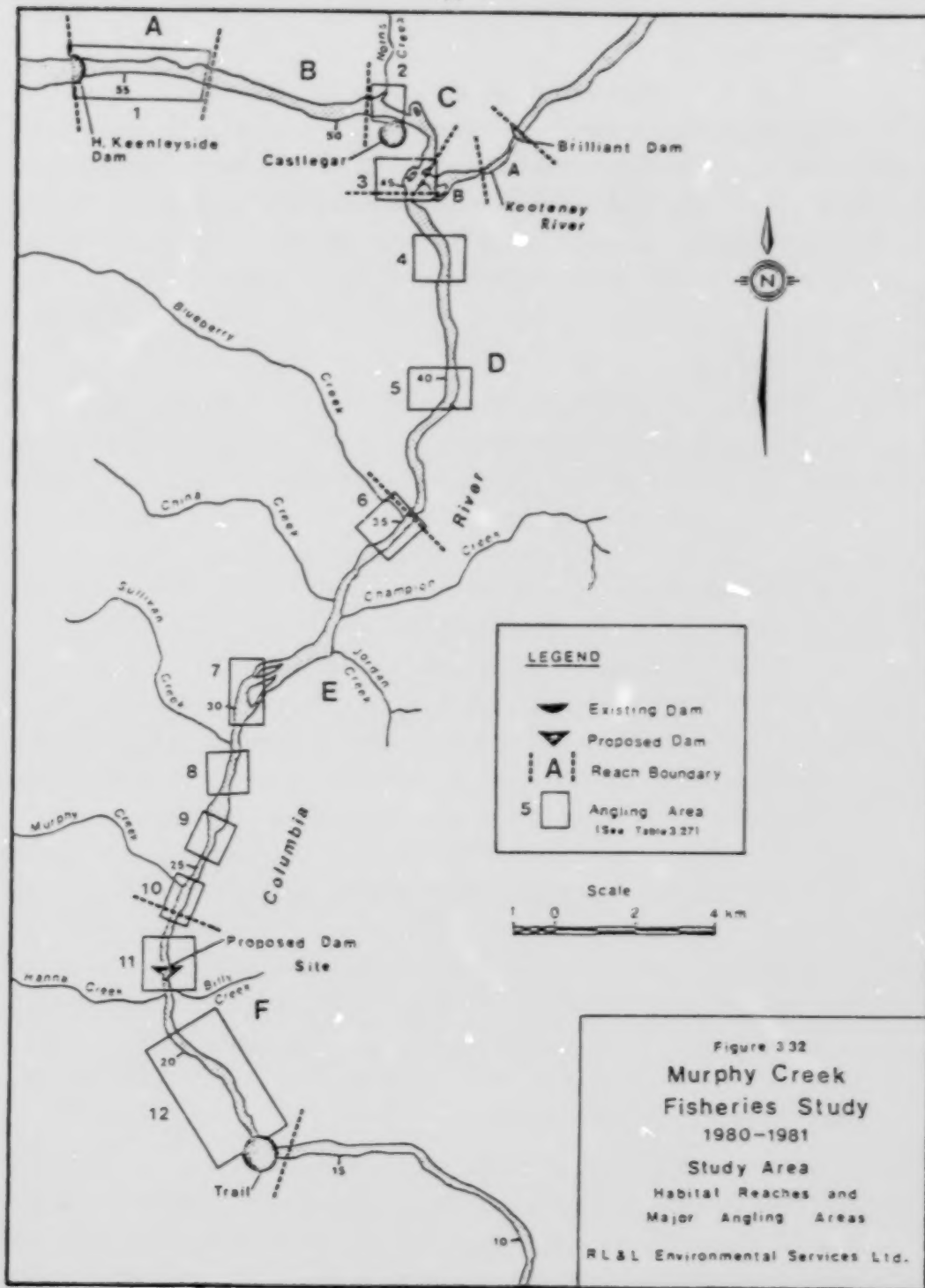


Table 3.27. Twelve major angling areas between Trail and Hugh Keenleyside Dam (data supplied by J. Stephenson, Edwin Reid and Associates Ltd., pers. comm.).

Site	Local Name	Km	Description
1	Below Hugh Keenleyside Dam	55.0	From the Hugh Keenleyside Dam downstream to the BC Timber Ltd.
2	Near Norns (Pass) Creek	48.5	At the confluence and in backwater on left side just downstream of confluence. ^a
3	Kootenay/Columbia confluence	45.6	In major eddies and backwaters in confluence.
4	Highway #3 bridge	42.9	Large backeddy just downstream of bridge.
5	Waterloo Eddy/D-Bar-D	39.2	Large eddy off a point on the left side.
6	Blueberry Creek	36.0	At the mouth, Poupore Eddy (Km 34.8) below on the right side, and a large eddy above the mouth on the left side.
7	Genelle	31.0	Major backwater and eddies around two large cobble bars.
8	Sullivan Creek	28.1	At mouth and small eddies along both banks.
9	Slough Eddy	25.5	Little and Big Slough Eddies on left side; also eddies on right side.
10	Murphy Creek	24.2	At mouth, and large eddies along right side.
11	Oasis	23.0	Series of eddies along right side.
12	Rivervale-Trail (First Bridge)	18.0	Series of eddies along both sides.

^a The section of the Columbia River between the Castlegar ferry and the CPR bridge has been closed to angling since the 1981 angling season.

Preferred fish species in the section between the Castlegar ferry and the Hugh Keenleyside Dam, in order of preference, are rainbow trout, Dolly Varden, kokanee, burbot, and walleye (B.C. Fish and Wildlife Branch 1981).

Most rainbow trout were caught immediately below the Hugh Keenleyside Dam and downstream of the Castlegar ferry. The estimated harvest of this species is 2150 fish/year (B.C. Fish and Wildlife Branch 1981). The CUE for rainbow trout ranged from 0.05 to 0.49, averaging 0.18 fish/rod h. This is considered high for a large, heavily exploited river but, when compared to catch rates in less exploited river systems in British Columbia, the value is relatively low. McLeod et al. (1978) calculated rainbow trout catch rates of 0.72 fish/rod h in the Parsnip River, B.C., 2.9 fish/rod h in the Hominka River (tributary to Parsnip River), and 1.7 fish/rod h in the McGregor River, B.C.

Fishing for Dolly Varden occurs mainly from December to May, with the greatest angling effort occurring immediately below the Hugh Keenleyside Dam. A catch rate of only 0 to 0.03 fish/rod h applied to Dolly Varden. The annual harvest of this species was estimated by the B.C. Fish and Wildlife Branch to be less than 100 fish/year. Angling for kokanee occurs primarily in late winter and spring, with little effort exerted for this species during summer and fall. Based on the 1980-1981 creel survey, the annual harvest of kokanee was estimated to be less than 1000 fish/year. This figure was considered to be low in light of earlier creel survey information for the area, and likely was due to the failure of the kokanee fishery to develop in the spring of 1981. The reason for the failure of the kokanee fishery is unknown.

Burbot are taken largely from the region immediately downstream of the dam, the main angling period being January through March. The annual harvest was estimated to be less than 250 fish/year. Walleye have only recently become a component of the sport fishery and it is believed that they move upstream into the study area from Lake Roosevelt. They are caught infrequently within the study area. The greatest angling efforts for white sturgeon occur immediately below the Hugh Keenleyside Dam, and between the Waneta Dam on the Pend Oreille River and the International Boundary on the Columbia River. It was estimated that approximately six sturgeon per

year are caught within the section of the Columbia River between the Hugh Keenleyside Dam and Trail; however, it also appears that sturgeon fishing is increasing in popularity, so annual catches may increase considerably during the next few years.

The majority of the fishermen in the study area were from nearby communities (Trail, Castlegar, Fruitvale), with a limited number being from other areas within British Columbia. Only 2% came from outside British Columbia. The high proportion of local anglers resulted in a relatively low number of hours angled per day (mean = 1.29 h/day/angler).

In summary, the Columbia River within the study area supports a diverse and successful sport fishery. The opportunity to catch a variety of sport species (e.g., rainbow trout, Dolly Varden, kokanee, mountain whitefish, sturgeon, brook trout, walleye, burbot, and chinook salmon) within a relatively short section of river, along with the opportunity to catch large individuals of certain species (e.g., rainbow trout, Dolly Varden, sturgeon) greatly contribute to the value of the sport fishery in the study area.

4.0 EFFECTS OF DEVELOPMENT

4.1 PROJECT DESCRIPTION^a

The Murphy Creek Project would involve the construction of a 28-m-high dam on the Columbia River approximately 3 km upstream of Trail, B.C. The dam would consist of a zoned, earth-rockfill embankment dam with a concrete cutoff wall extending some 250 m into the east abutment to seal the buried channel. The powerhouse, located on the west bank of the river, would contain five vertical shaft turbine units for a total installed capacity of 300 MW. Each turbine would have a rated flow capacity of approximately $525 \text{ m}^3/\text{s}$, for a combined five-unit discharge of $2625 \text{ m}^3/\text{s}$. The dam would create a reservoir approximately 34 km long, which would extend upstream to the base of the Hugh Keenleyside Dam on the Columbia River, and to the base of the Brilliant Dam on the Kootenay River. Three alternative reservoir normal operating levels (NOL) originally were investigated for purposes of the environmental impact assessment; these were elevations 424 m, 427 m, and 430 m.

On the basis of the feasibility studies, B.C. Hydro has selected the 424-m reservoir normal operating elevation for the Murphy Creek Project. Although the higher reservoir elevation would be economically more attractive, a Murphy Creek Project reservoir level at elevation 424 m in combination with a proposed power development at the Hugh Keenleyside Dam (Keenleyside Powerplant Project) would provide a power development close to optimum (B.C. Hydro 1982). Also, the lower reservoir elevation would reduce flooding of permanent homes and municipal facilities, and generally would have a lesser impact on the environment within the study area.

^aA large portion of the information describing the physical aspects of the project was taken from the "Murphy Creek Prefeasibility Study" (B.C. Hydro 1978), the "Columbia River Murphy Creek Project Feasibility Study" (B.C. Hydro 1981b), and the "Columbia River-Murphy Creek Project Engineering Description" (B.C. Hydro 1982).

The surface area of the Murphy Creek Project reservoir (based on NOL at el. 424 m) would be 1319 ha (B.C. Hydro, unpublished data). The area-storage capacity curves are shown in Figure 4.1 and the data from which the curves were drawn are given in Appendix G.

Two operating regimes have been considered for the Murphy Creek Project. The differences between the two operating regimes occur as a result of a stipulation in the Columbia River Treaty that the Arrow Lakes Reservoir be partially evacuated for flood control purposes by 1 May of each year.

Under operating Regime 1, which is based on the existing discharge regime at the High Keenleyside Dam, the Murphy Creek reservoir would be drawn down on an annual basis in order to facilitate the evacuation of water stored in the Arrow Lakes reservoir. Under normal operation the Murphy Creek reservoir would be drawn down during the period January to April (Figure 4.2). Between April and June, the reservoir would be filled to the normal operating level at el. 424 m.

Under Regime 2, the hydraulic heads at both the Hugh Keenleyside Dam and the Murphy Creek Dam would be maximized for power production. With this regime, the Murphy Creek reservoir would be operated for the majority of the year at the normal operating level (el. 424 m)(Figure 4.2).

Under either operating regime, daily reservoir water level fluctuations up to 2.0 m would occur at the dam during the March to May period, with the daily fluctuations in the other months limited to 1.5 m. Daily fluctuations upstream of the dam would be slightly less depending on location and inflow. Daily fluctuations of the tailwater level at the dam would be limited to 3.0 m with hourly variations of up to 1.0 m.

For most of the project life, Regime 2 is expected to be more representative of operation than Regime 1, and therefore has been chosen as the basis of project design. When the operating flexibility of the Columbia River Treaty projects improves following expiration of the Treaty (year 2024)

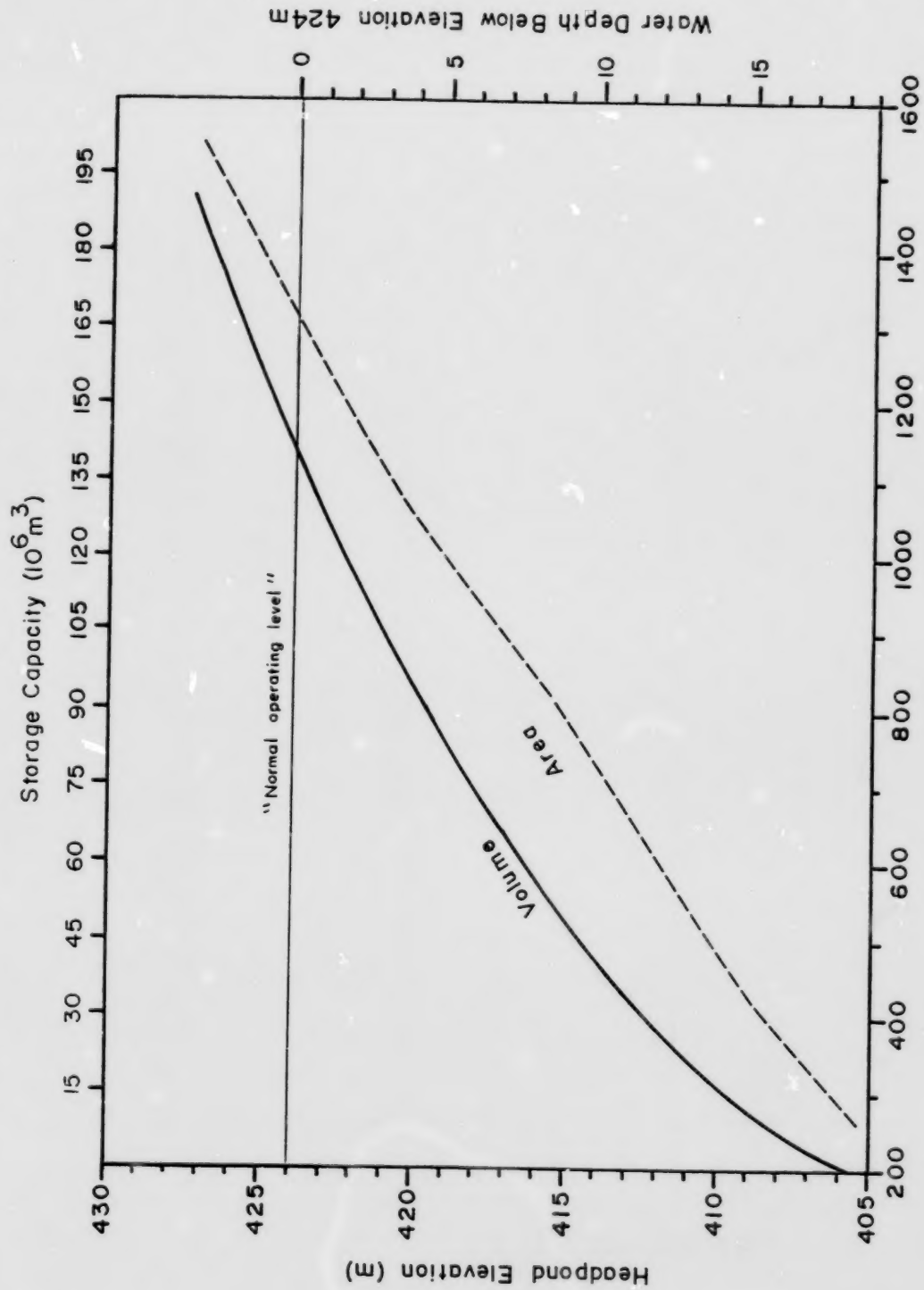


Figure 4.1. Area and storage capacity curves for the Murphy Creek reservoir (source: B.C. Hydro, unpublished data).

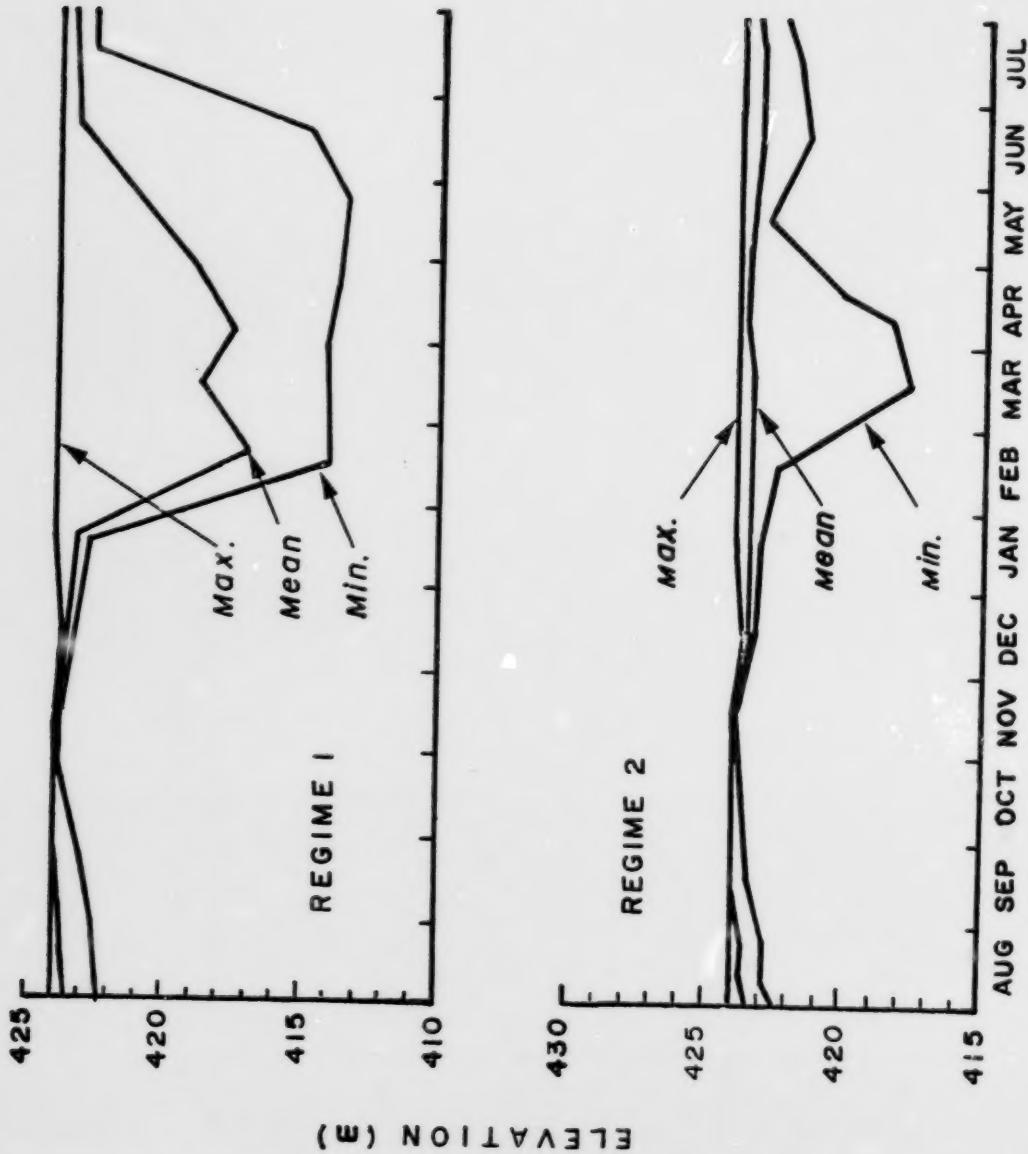


Figure 4.2. Simulated level of Murphy Creek reservoir operated under Regime 1 and Regime 2. (Adapted from B.C. Hydro 1982).

it is expected that the operating regime may be further refined to increase power generation, improve flood control at Trail, or reduce the environmental impacts of reservoir drawdown.

Although the project design has been based on operating Regime 2, there is no certainty that this regime would be in effect immediately following completion of the project. As a result, it has been assumed that there would be a period with the project operating under Regime 1. As Regime 1 would have the most serious impacts on sport fish within the study area, most of the impacts described in the following sections specifically address Regime 1 (i.e., worst case). Where substantial differences in the severity of impacts occur between the two operating regimes, the differences have been noted.

4.2 DESIGN AND PRE-CONSTRUCTION PHASE

During this phase of the project, minor impacts may occur to the fisheries resources in the study area due to the following:

- (1) fish mortalities as a result of biological studies;
- (2) increased harvest due to increased fishing pressure or increased efficiency of anglers; and
- (3) alteration of fish habitat resulting from site drilling or other activities associated with the project site.

Biological studies of the fish populations are necessary to provide an understanding of the status and composition of the fisheries resource in the project area so that the probable impacts of the project can be assessed. Although the present studies have been commissioned to evaluate the effects of the proposed project, the information collected will be useful in management of the fisheries resource in the area, either with or without the project. As the number of sport fish that have been sacrificed has been kept to a minimum, it is felt that the number of fish killed for scientific purposes will have only a negligible impact on the fish populations in the study area.

During the initial phases of the project, slight increases in angling pressure may be exerted on the fish populations in the study area. Increased

publicity (e.g., public meetings, newspaper reports, etc.) may result in greater awareness by the general public with respect to the quality of the sport fishery in the river. Also, if local people feel that their fishery may be affected by the project, they may react by attempting to utilize the resource to its fullest extent while the opportunity exists. Another potential source of angling pressure would result from the influx of persons to the area specifically because of the Murphy Creek Project (e.g., B.C. Hydro employees, consultants, contractors). It also is possible that, as a result of information obtained during the recreational surveys or biological studies, angler efficiency may increase slightly (i.e., anglers may try for other species, or may fish at locations identified as being most productive). It is not possible to accurately predict the extent of increased fishing activity or increased efficiency; however, it is felt that it would be small relative to the normal angling pressure.

Ancillary project actions in the vicinity of the damsite (e.g., test drilling, borrow area testing) would result in terrain disturbances; this, in turn, may cause increased suspended sediment input into the Columbia River. High suspended sediment levels and subsequent deposition are known to adversely affect fish habitat; however, due to the small amount of terrain likely to be disturbed, increases in suspended sediment levels during the pre-construction phase are expected to be small, assuming effective erosion control measures are employed. For this reason, ancillary activities are likely to have a negligible effect on downstream aquatic habitat and fish populations.

4.3 CONSTRUCTION PHASE

Construction activities could affect fish populations and fish production in a number of ways. The major effects may be associated with the following:

- (1) blockage of fish migrations at the construction site;
- (2) alterations to water quality, primarily downstream of the construction site;
- (3) reduction in streamflow during certain periods to facilitate construction;

- (4) increased angling pressure by construction workers;
- (5) the use of explosives during site excavation; and
- (6) the construction of ancillary facilities (e.g., borrow areas, spoil areas etc.), and the relocation of the highway and railroad.

4.3.1 BLOCKAGE OF FISH MIGRATIONS

During the construction period, river flows would be manipulated in stages. Initially, the river channel would be constricted toward the east bank by a cellular cofferdam to allow construction of the powerhouse and spillway. River constriction may result in a velocity hindrance or barrier to fish attempting to move upstream past the construction site. Upon completion of the spillway, the entire flow of the river would pass through the spillway while the remainder of the dam is completed. At this stage, upstream fish passage would be completely blocked unless fish passage facilities are provided. If the upstream movement of fish is blocked during construction, any species that undergo an annual downstream migration may be trapped below the dam at its completion. As a result, stocks of certain species (e.g., walleye), may be absent or inadequate to populate the future reservoir.

Fish movement patterns within the study area are largely undefined at the present time; however, it is apparent that species such as walleye and chinook salmon (species originally stocked or present in Lake Roosevelt) have moved upstream past the damsite into the study area. Based on available information, it appears that up to 5000 kokanee migrate upstream past the damsite each year to spawn in Norns Creek. A substantial portion of the rainbow trout population that spawns in Norns Creek also has been shown to move past the proposed damsite. In addition, it is likely that other sport fish (e.g., Dolly Varden, mountain whitefish, white sturgeon, walleye) undertake local movements which would take some individuals past the damsite.

4.3.2 DECREASED WATER QUALITY

Construction activities associated with the Murphy Creek dam and ancillary facilities would result in increased suspended sediment levels and subsequent deposition downstream of the construction site. Sediment input

would result from erosion of disturbed terrain (e.g., grading of slopes at the damsite, reservoir clearing activities, construction and maintenance of roads, etc.), gravel washing activities, or instream construction activities (e.g., coffer dam construction). The potential detrimental effects of increased suspended sediment levels on aquatic systems are well documented (Cordone and Kelley 1961; European Inland Fisheries Advisory Committee 1964; Hynes 1973). As discussed by Griffiths and Walton (1978), direct effects on fish include

- (1) mortality,
- (2) impairment of reproduction, growth, and survival, and
- (3) increase in disease;

while indirect effects involve

- (1) habitat modifications,
- (2) alterations in food sources and other biotic relationships, and
- (3) visibility reduction.

Sediment deposition may reduce incubation success of certain sport fish species that likely spawn in downstream areas of the Columbia River (i.e., mountain whitefish and possibly kokanee and rainbow trout).

The magnitude and duration of sediment effects will depend on the extent to which erosion is controlled during construction; however, due to the nature of the project, periods of increased suspended sediment levels during the approximate 6-year construction period are inevitable. Since the aquatic organisms in the lower Columbia River are adapted to clear water conditions (i.e., turbidity generally is less than 1 JTU in the Columbia River), they are likely to be more susceptible to increases in suspended sediment than are organisms acclimated in streams with high suspended sediment levels, or in streams with wide fluctuations in sediment load.

Spillage or seepage of gasoline, oil, greases, drilling fluids, or other toxic chemicals into the Columbia River could affect fish or fish food organisms in downstream areas. The magnitude of such an impact would be dependent on the amount and toxicity of the material entering the river. Proper precautionary measures will greatly reduce the probability of occur-

rence, but if a large spill of highly toxic material occurs, a massive fish kill could result.

The influx of workers and their families into the area during the construction period would result in an additional output of sewage. Present plans include the construction of camp facilities to house up to 600 people (year 3) with kitchen facilities to accommodate another 200 people (Bowman Engineering Associates Ltd. 1982). The camp location is planned for the site immediately downstream of the dam axis on the west bank of the river adjacent to Rivervale. It is expected that the sewage from the camp (270 L/day/capita) would be treated and discharged into the Columbia River.

The additional sewage resulting from increased population in the area would cause an increase in nutrient loads entering the Columbia River. Sewage effluents can have either positive or negative effects on the aquatic ecosystem. If the amount of organic matter and nutrients entering the system is above the assimilative capacity of the river, significant decreases in dissolved oxygen levels may occur which, in turn, may reduce the zoobenthos and sport fish populations. Also, nuisance growths of algae could occur. Alternatively, small amounts of sewage effluent within a stream can result in moderate fertilization or enrichment of the stream, causing an overall increase in zoobenthos and fish productivity. Due to the large size of the Columbia River (i.e., high flows) in relation to the potential amount of sewage associated with the construction phase, the Columbia River would be able to effectively assimilate the additional sewage outflow due to the project, provided that proper treatment and discharge facilities are utilized.

4.3.3 REDUCED STREAMFLOW

During construction of hydroelectric dams on previously regulated rivers, the discharge from existing upstream impoundments is often reduced for specific time periods to facilitate dam construction (e.g., during construction of a cofferdam). If this occurs during the Murphy Creek Project construction period, it may have a deleterious effect on invertebrate and fish populations downstream of the regulating impoundments (i.e., downstream of the Hugh Keenleyside Dam and the Brilliant Dam). Unseasonally low flows

may affect fish by reducing the amount of overall habitat available (including the amount of rearing habitat) which may lead to reduced growth rates or to an increase in density-dependent mortality (e.g., due to predation). Lower than normal water levels would affect zoobenthic production due to loss of habitat, dessication, altered flow conditions, increased drift, etc. It also may affect fish reproduction (depending on timing of the lowering of water levels) due to dessication of eggs. It is not possible at the present time to predict the probability or the magnitude of this potential impact since the precise water level requirements during critical construction periods are unknown. However, certain factors may tend to reduce the impacts of low flows. For example, minimum flow releases required as part of the Columbia River Treaty will limit the timing and magnitude of flow reduction (i.e., minimum flow of $142 \text{ m}^3/\text{s}$). Also, the aquatic fauna of the Columbia River represents a community adapted to the frequent variation of discharge that occurs under the present (regulated) conditions. This would serve to reduce incremental impacts of low flows, relative to an unregulated river.

4.3.4 INCREASED ANGLING PRESSURE

During the construction period, large numbers of workers would be present in the study area. The construction work force required is expected to be as follows (DPA 1983):

<u>Construction Year</u>	<u>Average No. of Workers</u>	<u>Peak No. of Workers</u>	<u>Construction Year</u>	<u>Average No. of Workers</u>	<u>Peak No. of Workers</u>
1	165	250	5	840	1000
2	345	450	6	470	670
3	760	980	7	75	200
4	935	1100			

The socio-economic study (DPA 1983) predicts that the majority of these workers would be hired locally. The influence of construction workers, their families, and persons associated with the service industries would result in an increase in sport fishing in the river. This could potentially lead to an overharvesting of the sport fish populations in localized areas.

4.3.5 USE OF EXPLOSIVES

Fish mortalities will occur if explosives are used in or near the channel during site excavation. The magnitude of this potential effect will be dependent on the extent of use of underwater explosives, (i.e. most blasting would be conducted "in the dry" behind coffer dams) and the numbers and species of fish near the site (e.g., a velocity barrier may block upstream movements and cause fish to congregate in the vicinity of the site). Concentrations of fish are most likely to occur during the spring or fall spawning migration periods.

4.3.6 CONSTRUCTION OF ANCILLARY FACILITIES, AND HIGHWAY/ RAILROAD RELOCATION

Additional impacts to the fisheries resources would occur as a result of construction of ancillary facilities such as site access roads, construction camps, borrow areas, and spoil areas, and as a result of construction activities associated with the relocation of sections of the highway (less than 1 km) and railroad (approximately 5 km). If proper construction practices and effective erosion control methods are used, the access roads and the relocated sections of the highway and railroad should have little long-term effect on the aquatic resources. Similarly, the construction camp should have only a minor effect, providing that surface runoff and sewage are properly treated prior to discharge into the river. Extraction of construction materials from borrow areas could have a serious detrimental effect on the aquatic resources. The borrow site that has been selected to provide the impervious embankment fill would be located along the left bank of Murphy Creek 4 km upstream from the Columbia River (B.C. Hydro 1982). This site is located approximately 50 m from the active creek channel. Excavation activities in this area potentially could result in alterations to the hydraulic characteristics of the stream which, in turn, could affect fish populations in the creek. The borrow activities either along Murphy Creek or on the terraces upstream of the damsite also may result in sediment transport into the tributaries and into the Columbia River. If gravel washing activities occur in association with the borrow removal operation, additional sediment

input to the Columbia River would occur. The deleterious effects of suspended sediment on aquatic resources was discussed previously in Section 4.3.2.

One area identified for potential use as a spoil disposal area is the Billy Creek valley, located approximately one kilometer downstream of the proposed damsite. Since Billy Creek is subject to intermittent flows and exhibits a very steep gradient, it was judged to have little or no fisheries value. As such, the use of this valley as a spoil disposal area should not have a significant effect on fish populations provided adequate erosion control methods are employed to prevent high suspended sediment loads entering the Columbia River.

A slight beneficial impact may occur as a result of proposed reservoir and railroad protection programs which would involve the placement of coarse material (gravels, cobbles, riprap) along unstable or erodible slopes. The presence of the coarse materials below the surface of the reservoir would provide habitat for aquatic invertebrates and cover for juvenile fishes. The coarse material also may provide spawning habitat for some fish species; however, the potential beneficial effects of these materials would be substantially reduced by the proposed daily fluctuation of reservoir levels.

4.4 OPERATIONAL PHASE

The construction of a dam transforms the terrestrial and riverine ecosystems in the affected area into a lacustrine (i.e., lake) system, or into a slower moving riverine system in the case of some run-of-the-river reservoirs. This results in physical, chemical, and biological changes as the reservoir develops and stabilizes. Due to the complexity of interactions that occur in a newly-formed reservoir, it is not possible to predict with certainty the effects of the development on the aquatic resources. The SCOPE Working Group on Man-Made Lakes (1972, p. 12) states that:

Man has no early prospect of being able accurately to judge all possible effects of a new lake. Whereas some of them, such as lake bed vegetation in given physical conditions may be predicted with guarded confidence, many of the

relationships are barely recognized, let alone sufficiently well understood to permit prediction. Moreover, the time dimensions of the processes at work differ greatly. The response of certain populations, such as plankton to the new water body may be almost instantaneous, while the formation of lake bottom soils, or indeed, of the whole lake system goes on over decades or centuries.

The major impacts on the aquatic resources that would accrue during the operational phase would be related to the following:

- (1) permanent blockage of fish migrations (assuming no fish passage facilities);
- (2) loss of riverine habitat;
- (3) loss of spawning habitat;
- (4) loss of rearing habitat;
- (5) the physical and biological changes associated with the reservoir and its operation; and
- (6) downstream effects.

4.4.1 BLOCKAGE OF FISH MIGRATIONS

A dam on the Columbia River near Trail would result in the permanent blockage of upstream migrations of fish if adequate fish passage facilities are not incorporated into the design of the dam. At the present time, fish stocks have access in the mainstem Columbia River from the Grand Coulee Dam upstream to the Hugh Keenleyside Dam and in the Kootenay River to the Brilliant Dam. Unconfirmed reports of walleye being caught in the Arrow Lakes Reservoir suggest that some species of fish may be able to successfully negotiate through the boat lock at the Hugh Keenleyside Dam; from there, they would have access through the Arrow Lakes Reservoir up to the Revelstoke damsite.

Two sport fish species which are known to have undertaken upstream movements past the proposed Murphy Creek damsite are walleye and chinook salmon. Both of these species have been captured only in recent years from the Columbia River within the study area. Walleye, a species that is non-native to the Columbia River system, has become established in Lake

Roosevelt in the United States. They first appeared in angler catches from Lake Roosevelt in the 1964-66 period. In 1980, walleye contributed 25% to the total catch in a test netting program conducted on the lake (R. Morgan, U.S. Fish and Wildlife Service, Grand Coulee, Wash., pers. comm.). It appears that, as the population expanded in Lake Roosevelt, walleye extended their range to include portions of the Columbia River in Canada. Recent increases in the catch of walleye from within the study area indicate that fairly large numbers presently are moving upstream past the site of the proposed Murphy Creek dam. Whether the walleye in the study area undertake an annual migration to and from Lake Roosevelt or remain within the study area as an established population is presently unknown.

The B.C. Fish and Wildlife Branch (1981) estimated angler catches of 39 chinook salmon during their 1980-1981 creel survey in the study area. These salmon undoubtedly came from stocks planted in Lake Roosevelt. During the period 1972-78, a total of 2.1 million juvenile fall chinook salmon were stocked in the lake by the Washington Department of Fisheries (L. Blankenship, Washington Department of Fisheries, Olympia, pers. comm.). The capture of chinook salmon in the study area only in June and July indicates that individuals may migrate into the study area during spring and early summer (for feeding purposes) and then return to downstream areas in late summer. The extent to which movements of this species would be affected by the proposed dam would be dependent on the continued abundance of this species in Lake Roosevelt. Since the stocking program has been largely unsuccessful in regard to enhancement of the sport fishery in the lake (i.e., substantially less than 1% of fish stocked have been taken by anglers), it is unlikely that the stocking program will continue (R. Duff, pers. comm.). Consequently, the chinook salmon population present within the study area likely would be absent or limited in numbers at the time of completion of the Murphy Creek Project.

Tagging studies conducted during the spring of 1981 have shown that a large segment of the rainbow trout population that spawns in Norns Creek and Champion Creek undergoes a post-spawning movement downstream to areas below the proposed damsite (i.e., six of 10 tag returns came from

rainbow trout recaptured downstream of the damsite and two were recaptured a short distance upstream of the damsite). It is apparent, therefore, that upstream movements of this species also would be affected seriously by the proposed Murphy Creek dam.

Movement patterns of other species within the study area are poorly known. Based on an analysis of size and growth characteristics of kokanee spawning in Norns Creek, it is speculated that the majority of these fish are migrant stock originating from Lake Roosevelt. This being the case, the spawning run would be blocked by the Murphy Creek dam, assuming that fish passage facilities are not incorporated. Even if this stock of kokanee is allowed access over the dam, much spawning habitat presently available in Norns Creek would be inundated by the reservoir.

Due to the small storage capacity of the Murphy Creek reservoir (i.e., hydraulic retention time of generally one day) and the narrow valley, a noticeable water current would exist through the reservoir (B.C. Hydro 1981a). This may cause large numbers of newly-hatched fry of certain species (i.e., those with poor swimming capability such as kokanee, suckers, and walleye) to be transported out of the reservoir (via the turbines or spillway) and into the river system below. Downstream movement of fry is typical for many fish species that rear in lakes and spawn in tributaries (e.g., kokanee). The subsequent upstream movement of downstream displaced fish in later years, however, would be blocked by the dam if suitable fish passage facilities are not incorporated.

In order to provide an indication of the order of magnitude of fish that may be blocked by the Murphy Creek dam, a preliminary estimate of the numbers of major sport fish that presently migrate upstream past the damsite has been provided in Table 4.1. It must be noted that in most cases these estimates have been based on limited information, and may be subject to considerable error; as such, the limitations of these estimates must be recognized.

Table 4.1. Preliminary estimates of the number of major sport fish which would be blocked by the Murphy Creek Dam.^a

Species	Probable Timing of Major Upstream Movement	Purpose of Movement	Estimated Numbers
Kokanee	August	Spawning	1500-5000 ^b
Rainbow trout	March-May year round	Spawning Feeding/random dispersion	200-750 ^c 500-1500 ^d
Dolly Varden	unknown	Spawning/feeding	less than 200 ^d
Mountain whitefish	year round October-February	Feeding/dispersion Spawning	500-5000 ^d 500-2500 ^d
Walleye	unknown	Feeding, possibly spawning	less than 1000 ^d
Chinook salmon	May-August	Feeding, possibly spawning	less than 500 ^e
Sturgeon	unknown	Feeding, possibly spawning	50-500 ^d

^aSince these estimates are based on limited data, they may be subject to considerable error; however, it was felt that an estimate should be attempted for a realistic consideration of incorporation of fish passage facilities.

^bAssumes spawners in Norns Creek and possibly some spawners in the mainstem migrate up from Lake Roosevelt.

^cPreliminary tag return information indicates that over one-half of the spawning population of rainbow trout utilizing Norns Creek migrate up from below the damsite. A portion of the rainbow trout that utilize other tributaries or spawn in the mainstem likely also move up from below the damsite.

^dNo data are available to base these estimates on; however, existing information in the published literature indicates that local movements likely would occur. The estimated numbers in this range seem reasonable based on abundance during the biological sampling program and from angler harvest estimates.

^eChinook salmon were stocked in Lake Roosevelt and have moved upstream past the damsite (i.e., they have been captured by anglers in the study area). Their abundance likely will be dependent on future stocking of Lake Roosevelt.

4.4.2 LOSS OF RIVERINE HABITAT

The Murphy Creek Project would result in the inundation of approximately 34 km of the mainstem Columbia and Kootenay rivers, and 3.0 km of major tributary streams (based on a normal reservoir operating level of el. 424 m). The reservoir would exhibit characteristics intermediate between a river and lake due to the presence of a noticeable current. This transformation from an existing river to a reservoir environment would greatly affect many of the aquatic organisms living in this system. Those species which are obligate rheophiles (i.e., those that are adapted only to running water) would be replaced by those species that are better adapted to living in slower flowing or lake type habitat. Some species that are presently abundant in the river system may be able to survive in the reservoir, but due to competition with better adapted species, may be eliminated over a period of years. The significance of the loss of riverine habitat will be discussed in greater detail in later sections.

4.4.3 LOSS OF SPAWNING HABITAT

The Murphy Creek Project would inundate virtually all of the upstream length of the mainstem Columbia and Kootenay rivers in the study area and would flood approximately 39% of the total length of tributary streams presently accessible to fish from the Columbia River (Table 4.2). The sections of tributary streams remaining above the reservoir generally have a steep gradient and only a low to moderate suitability for spawning by salmonids (e.g., rainbow trout, kokanee, Dolly Varden). Inundation, therefore, would alter or eliminate much of the suitable spawning habitat for stream spawning salmonid species.

In order to better quantify loss of spawning habitat, a preliminary application of the Habitat Evaluation Procedure as developed by the U.S. Fish and Wildlife Service (1980) was used. The major tributaries that would be flooded were evaluated as to their suitability for spawning by salmonid species (e.g., rainbow trout and kokanee) (Appendix F). The number of spawning habitat units (SHU) were calculated based on estimated stream area and average suitability for spawning. The habitat units that would be lost as

Table 4.2. Estimated stream loss due to reservoir inundation and extent of accessible stream remaining in the major tributaries to the Murphy Creek Reservoir at the proposed normal reservoir operating level (NOL) of el. 424 m, and at the two alternatives investigated.

Stream	Accessible Length of Stream Flooded				Length Accessible Above NOL								
	el. 424 m		el. 427 m		el. 430 m		el. 424 m		el. 427 m		el. 430 m		
	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
Total Length													
Accessible to Fish (m)	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
Norns Creek	2200	1360	61.8	1820	82.7	1970	89.5	840	38.2	380	17.3	230	10.5
Champion Creek	2500	440	17.6	640	25.6	770	30.8	2060	82.4	1860	74.4	1730	69.2
Blueberry Creek	1100	500	45.5	560	50.9	650	59.1	600	54.5	540	49.1	450	40.9
China Creek	1100	330	30.0	380	34.5	440	40.0	770	70.0	720	65.5	660	60.0
Sullivan Creek	50	50 ^a	100.0	50 ^a	100.0	50 ^a	100.0	80 ^b	160.0	70 ^b	140.0	60 ^b	120.0
Murphy	600	290	48.3	300	50.0	370	61.7	310	51.7	300	50.0	230	38.3
Total	7550	2970	39.3	3750	49.7	4250	56.3	4660	61.7	3870	51.3	3360	44.5

^a The reservoir would inundate the railroad culvert which, at the present time, appears to be a blockage to fish. It is felt that after inundation fish may have access via the flooded culvert to sections of Sullivan Creek upstream of the railroad tracks. Total length of stream inundated, therefore, would be as follows: el. 424 m = 130 m; el. 427 m = 140 m; el. 430 m = 150 m.

^b net length of improved access = 10 to 30 m depending on normal reservoir operating level.

a result of flooding were then evaluated for the proposed reservoir elevation of el. 424 m, and the alternative reservoir levels that were being investigated. The results show that for the proposed Murphy Creek reservoir (el. 424 m), approximately 56% of the accessible spawning habitat units would be inundated (Table 4.3). For the alternative reservoir operating levels of el. 427 m and el. 430 m, approximately 74% and 78% of the spawning habitat units, respectively, would be inundated. In Norns Creek, 73% of the SHU's would be flooded at the proposed normal operating level (el. 424 m).

At present, rainbow trout utilize accessible portions of the major tributaries (e.g., Norns, Champion, Blueberry, China, and Murphy creeks) for spawning and rearing. Inundation of these creeks would alter existing hydraulic characteristics including depth, velocity, and water percolation rates through the gravel substrate. The reduced water velocity in the inundated sections of the streams may increase the rate of sediment deposition, and also prevent annual scouring of the substrate during freshet periods. These factors would reduce the suitability of the inundated sections of the tributaries for rainbow trout spawning.

The majority of the spawning habitat in the mainstem Columbia and Kootenay rivers presently utilized by rainbow trout, Dolly Varden, and mountain whitefish also would be inundated. Species such as mountain whitefish may reproduce in the reservoir by spawning in nearshore areas or near the upper limit of flooding in tributaries; however, the late winter drawdown required under operating Regime 1 likely would result in high mortality at the egg incubation stage (i.e., due to dessication and freezing). It is doubtful if any of the fall or winter spawning species that normally spawn in the mainstem would be able to locate suitable spawning habitat under post-impoundment conditions during the period when the reservoir is operated according to Regime 1. Once the project begins operating under Regime 2, the reservoir would become more suitable for fall spawning species, although the daily water level fluctuation of up to 2.0 m in the March to May period would still limit the extent of use (i.e., the eggs would have to be deposited at a depth greater than 2 m). Also, the drawdown of the reservoir during certain years (i.e., extreme conditions) similarly would reduce the suitability of the reservoir for spawning.

Table 4.3.

Estimated spawning habitat units (SHU)^a lost due to reservoir inundation and spawning habitat units remaining in the accessible portion of the major tributaries to the Murphy Creek Reservoir at the proposed normal reservoir operating level of el. 424 m, and at the two alternatives investigated. See Appendix F for description of H.E.P. Methodology and suitability criteria used.

Stream	Total SHU Available to Fish	SHU Lost by Inundation				Accessible SHU Remaining			
		el. 424 m		el. 427 m		el. 424 m		el. 427 m	
		SHU	%	SHU	%	SHU	%	SHU	%
Norns Creek	24937	18311	73	24374	98	6626	27	563	2
Champion Creek	6923	1139	16	1686	24	5784	84	5237	76
Blueberry Creek	3707	1350	37	1512	41	2357	63	2195	59
China Creek	2670	871	33	1003	38	1799	67	1667	62
Murphy Creek	1242	600	48	621	50	642	52	621	50
Total	39479	22271	56	29196	74	17208	44	10283	26

^a Spawning habitat units expressed in m².

4.4.4 LOSS OF REARING HABITAT

Inundation associated with the Murphy Creek Project would reduce substantially the availability of suitable rearing habitat for newly hatched and juvenile life stages of salmonid species. Rainbow trout rear in most of the major tributaries for at least the first year of life. Although inundation of the lower sections of the tributaries would increase the total amount of aquatic habitat available for rearing, the altered habitat (i.e., deeper, lower velocity) would be of lower quality due to reduced cover, increased vulnerability to predators, and lowered aquatic insect populations (i.e., due to fewer riffles, increased sediment deposition, daily water level fluctuations, etc.).

In the mainstem Columbia River, young-of-the-year rainbow trout rear primarily in nearshore areas where they likely prey upon food organisms transported by the current (i.e., plankton from upstream impoundments or drifting benthic invertebrates). The suitability of nearshore habitat in the impoundment is difficult to predict; however, expected reductions in current velocity and benthic productivity, and high daily water level fluctuations likely would reduce substantially the quality of these areas for trout rearing.

Rearing habitat for species that are better adapted to slow water conditions may be enhanced within the reservoir. For example, lake whitefish have shown a substantial increase in numbers since impoundment in Lake Roosevelt (R. Duff, pers. comm.). Kokanee also are generally a lake rearing species; as such, the Murphy Creek reservoir may expand the rearing habitat available to this species. Suckers and many of the other coarse fish species (e.g., reidside shiners, peamouth, northern squawfish) likely would be able to adapt to the reservoir conditions in regard to rearing habitat.

4.4.5 MURPHY CREEK RESERVOIR

4.4.5.1 Water Quality

Due to the small storage capacity of the reservoir relative to the inflow/outflow, the hydraulic retention time (residence time) is very short, generally less than 1 day; as a consequence, water quality within the

reservoir would be very similar to that of the present river. International Environmental Consultants Ltd. (IEC) documented the expected impacts of the development on the water quality (IEC 1981); their predictions are summarized in the following sections.

(a) Temperature

Based on modelling of the proposed reservoir thermal characteristics, IEC (1981) predicted that no significant increase in temperature should occur in the surface layer and that thermal stratification would not occur under the conditions examined. They also felt that the temperature of the water exiting the Murphy Creek reservoir would be similar to present river conditions. Ice is expected to form on the reservoir only infrequently, probably less than once in every 70 years (B.C. Hydro 1981a).

(b) Dissolved Gases

Dissolved oxygen concentrations in the reservoir are expected to remain well above the minimum levels required to maintain sport fish populations. IEC (1981) predicted that total dissolved gas supersaturation would be reduced in the reservoir during much of the year due to a reduction in the head across the Hugh Keenleyside Dam. Also, the incorporation of turbines into the Hugh Keenleyside Dam is expected to reduce dissolved gas saturation levels. The reduction of dissolved gas concentrations would be beneficial to downstream fish populations, since the concentration of dissolved gases periodically occurring in the river at the present time (i.e., up to 144% saturation) is high enough to be lethal to fish. It is thought that most fish avoid problems during periods of high dissolved gas concentrations by remaining in deep water throughout most of the day, possibly moving into the shallows only for short periods of time.

(c) Nutrients

Concentrations and loadings of dissolved nutrients are expected to remain similar to those occurring at present.

(d) Colour

IEC (1981) predicted that the reservoir would not significantly change the dispersion characteristics of the BC Timber Ltd. effluent plume; therefore, high colour levels can be expected in the reservoir downstream of the effluent outfall.

(e) Suspended Sediment Regime

Turbidity levels in the reservoir are expected to be low due to limited sediment input from major inflows (i.e., primarily due to settling in upstream impoundments)(B.C. Hydro 1981a). Short periods of increased turbidity likely would occur in response to sediment inputs from tributary streams during freshets. Also, suspended sediment levels (and turbidity) would increase slightly in the initial years of operation, since some bank sloughing and beaching are expected when the water level is raised (B.C. Hydro 1981a).

4.4.5.2 Biological Productivity

A large number of complex biotic and abiotic factors interact to control the biological productivity of an aquatic system. Some of the more obvious interacting components include edaphic factors (Rawson 1939; Sparrow 1966), the type and distribution of organic material in the basin (Edmondson 1957), the morphometry of the basin (Rawson 1952; Ryder 1965), nutrient influx from upstream areas (Hynes 1970), climatic factors (Rawson 1942; Talling 1966; Brylinsky and Mann 1973), turbidity and the depth of light penetration (Murphy 1962), hydraulic retention time (Nursall 1952; Taylor 1971), and the biological species present. Due to the complexity of the interactions which may occur within the system, it is difficult to predict, with certainty, the biological characteristics of the future reservoir. However, some general trends can be predicted based on previous studies and the known characteristics of the proposed reservoir.

(a) Littoral Areas

It is well known that the shallow, nearshore regions are highly productive areas in aquatic ecosystems (Reid 1961; Wetzel 1975). This littoral zone, defined by Ruttner (1963) as "that portion of the shoreward profile inhabited by autotrophic plants and sessile algae," is normally very important for fish production. Zoobenthos, a major food source for fish, generally are more abundant in shallow waters where aquatic plants are present (Reid 1961). Aquatic plants and benthic algae often are used as cover by both juvenile and adult fish. Also, numerous fish species (especially cyprinids) utilize vegetation for spawning.

The morphometry of the Murphy Creek reservoir would reflect its location within a steep-sided, narrow river valley. The proportion of reservoir area that will have a maximum depth less than 1 m (based on el. 424 m normal operating level) would be approximately 65 ha (5% of surface area); the area with a depth less than 10 m (generally the maximum depth to which macrophytes are found according to Ruttner 1963) would be approximately 550 ha (42% of the surface area).

Operating Regime 1 would severely restrict the development of aquatic macrophytes in the littoral zone of the reservoir. Although water levels would fluctuate up to 1.5 m (on a daily basis) during the major part of the growing season, the reservoir would be drawn down during the January to June period to allow evacuation of the Arrow Lakes. This lowering of the water levels in the Murphy Creek reservoir would expose approximately 332 ha or 25% of the surface area and would subject any aquatic plants that have developed in this region to dessication and/or freezing. The harsh environment within the drawdown area, therefore, likely would prevent or severely restrict the development of aquatic vegetation communities in the reservoir. Reid (1961) noted that reservoirs with fluctuating water levels generally have little rooted aquatic vegetation. Cooke (1980) noted that drawdown can be used to control rooted aquatic macrophytes when there is nearly complete dewatering of the sediments and a sufficient (1 month or more) period of cold (freezing) or heat. The long drawdown period in the Murphy Creek reservoir during the winter (January to June) under Regime 1

would, however, likely limit the establishment of most species of aquatic macrophytes; however, limited growth of some of the more tolerant species may occur within or below the drawdown zone. Van der Valk and Davis (1978) noted that certain species of *Potamogeton*, *Scirpus*, *Sparganium*, and *Ceratophyllum* are tolerant to dessication.

Under operating Regime 2, aquatic macrophytes are expected to become established in depositional areas along the periphery of the reservoir. Due to daily water level fluctuations of up to 2.0 m during the March to May period and 1.5 m during the rest of the year, it is likely that macrophytes would be abundant only in suitable areas (i.e., depositional, gently sloping), below the 1.5-m depth contour in the reservoir. Since the reservoir is expected to be clear, macrophytes may grow at depths as great as 5 to 10 m.

Benthic algae would be expected to develop within the reservoir, particularly in areas of firm or relatively stable substrates. Current and substrate type would be the two main factors in determining the types and relative abundance of the benthic algae that would occur. As a group they would be better adapted to changing water levels because of their shorter life cycles (i.e., they can colonize newly flooded substrates quickly). Nevertheless, the seasonal drawdown under operating Regime 1 will detrimentally affect their overall success relative to a more stable system.

(b) Phytoplankton and Zooplankton

When a reservoir is first created, nutrients leaching from the soils, flooded vegetation, and organic detritus usually increase nutrient levels in the water which, in turn, facilitates increased phytoplankton and benthic algae production (Funk and Gaufin 1971; Zhadin and Gerd 1973). In view of the small area flooded and the extremely low water retention time in the Murphy Creek reservoir, nutrient levels are not expected to increase significantly (IEC 1981). Also, the rapid flushing rate would severely limit phytoplankton production in the reservoir. Similarly, zooplankton production would not be enhanced to any significant degree. However, there will be a continual source of phytoplankton, zooplankton, and organic detritus entering the reservoir from upstream impoundments (i.e., Arrow Lakes Reservoir and

Kootenay Lake), which would act as a direct or indirect energy source for organisms in the reservoir. The amount of phytoplankton and zooplankton entering the system would be the same as that entering the present river system; thus, no significant increase in production would likely occur in the reservoir as a result of these inputs. Since river ecosystems can be very effective in utilizing plankton and particulate organic material from lake or reservoir outflows (Hynes 1970), there could in fact be a decrease in the utilization of organic inputs in the reservoir system relative to the present river. This could occur if organisms which can utilize the food source (e.g., filter feeding benthos, plankton feeding fish) are incapable of harvesting the food source prior to its leaving the reservoir. Nevertheless, the non-utilized material would quickly be assimilated below the Murphy Creek dam.

Mysids entering the river system from Arrow Lakes Reservoir and possibly from Kootenay Lake are an important food item for kokanee and other fish species in the study area (Lindsay 1976; present study). In lakes, mysids undertake a diurnal vertical migration (Gosho 1975), and are in the upper part of the water column only during the night; thus, they are accessible to fish only for a short period of time (i.e., late evening and early morning) during the active fish feeding periods. Once the mysids enter the river, however, they are highly susceptible to capture by fish since they cannot swim effectively in strong currents. After the reservoir has been created, water velocities in the main body of the reservoir may be low enough to allow the mysids to sink to the bottom during the daytime, thereby avoiding predation during periods of active feeding by fish. Thus, mysids may become less available to fish populations in the reservoir area after impoundment. The extent to which this may happen is unknown since it is not clear how well the mysids will cope with currents in the reservoir. As the mysids are carried out of the Murphy Creek reservoir by the current (similar to the way they entered the reservoir), they would become available to fish in the downstream areas. This may increase fish production in river reaches downstream of the outflow relative to present conditions.

(c) Zoobenthos

Impoundment of the Columbia River by the Murphy Creek dam would have a significant effect on the benthic invertebrate populations in the study area. Lyakov (1973) has identified three major stages that occur when a river is impounded and a lake-type reservoir is created. The first stage is the alteration of the original invertebrate community. Those aquatic insects that are adapted only to running water (obligate rheophilic organisms) are significantly reduced in numbers. These organisms generally include certain species of the mayflies, stoneflies, and caddisflies which are important components of the present diet of fish. Alteration of the benthos community is caused by the elimination of current, and the intensive modification of the substrate (Gurvich 1973) due to deposition of sands or silts from shoreline erosion. The transition from a riverine benthic fauna to a lake type fauna, and the colonization of the newly flooded areas occurs rapidly, usually after 1 to 3 years (Paterson and Fernando 1970; Gurvich 1973).

The second stage after impoundment is the temporary period of oligochaete biocenosis. During this period, there is rapid expansion of oligochaete and chironomid populations. This increase is caused primarily by an accumulation of sediment, and an abundance of organic detritus that is provided by the flooded terrestrial vegetation (Gurvich 1973). The final stage of benthic invertebrate colonization involves the establishment of permanent, more stable populations of species well adapted to the specific reservoir conditions. According to Lyakov (1973), species diversity generally is low, with only a few species exhibiting high abundance. Achievement of this stage may take up to 10 years (Lyakov 1973).

Although a general shift from riverine benthic fauna to lake-type fauna likely would occur in the Murphy Creek reservoir, the changes should not be as dramatic as described by Lyakov (1973) since the water velocity within the Murphy Creek reservoir would be high relative to most other impoundments. Depending on the specific water velocities that would occur along the shoreline of the reservoir, certain riverine benthic fauna may be better adapted to the conditions than most lacustrine species.

The annual drawdown required in the Murphy Creek reservoir under operating Regime 1 would severely restrict the development of zoobenthos in the reservoir. Fillion (1967) studied benthic invertebrates in three reservoirs on the Kananaskis River system in Alberta; he determined that the maximum densities of benthic invertebrates occurred at or below the lower limits of the drawdown. In natural lakes the maximum densities occur in the shallow water areas. Grimas (1961) recorded a loss of 70% of the bottom fauna in the regulated zone in Lake Blasjon Sweden. The timing of the drawdown in the Murphy Creek reservoir also may have a detrimental effect on zoobenthos within the drawdown area. Paterson and Fernando (1969; 1970), Isom (1971), and Benson and Hudson (1975) reported that freezing of the exposed substrate during drawdown resulted in high mortality of the benthic invertebrates buried within the substrate. Since the Murphy Creek reservoir would be at the normal operating level during most of the active growing season (June to September), some recolonization of the drawdown area by benthos would likely occur. Paterson and Fernando (1969) noted a rapid dispersal of chironomids into the drawdown zone after reflooding of the previously exposed substrate. Other motile species such as mayflies and caddisflies also may colonize the drawdown area after reflooding; however, the littoral benthic fauna is expected to remain sparse.

The expected daily water level fluctuations (both Regime 1 and Regime 2) of up to 2.0 m in the March to May period and 1.5 m in other months, would restrict benthic production in the shallow water areas of the reservoir. This would reduce the value of shoreline areas of the reservoir as rearing or feeding areas for fish.

(d) Fish

The general sequence of events that occurs when a river is impounded as it relates to fish populations has been reviewed and discussed by various authors including Ellis (1941), Kimsey (1957), Cooper (1956), Poddubny (1971), Lowe-McConnell (1973), Nilsson (1973), Machniak (1975), and Baxter and Glaude (1980).

As previously noted, impoundment of a river to form a lentic system generally leads to an increase in nutrients in the water due to leaching from flooded vegetation and soils. The nutrients are quickly assimilated by the phytoplankton, which leads to increased zooplankton populations. The greater availability of fish food organisms results in higher fish production; however, the initial fish production rate generally declines to a long-term sustainable level that is approximately one-half of the peak level recorded. Reservoirs typically exhibit a lower fish species diversity than occurred naturally; in addition, species composition often shifts from an initial assemblage dominated by piscivorous sport fish species, towards one composed of a higher proportion of coarse fish species.

It is doubtful that the typical sequence of events as described would occur in the Murphy Creek reservoir for a number of reasons. Due to the configuration of the river valley, the terrestrial area subject to inundation would be small (about 285 ha). Also, the extremely short water retention time would result in rapid flushing of nutrients leached from the flooded vegetation or soil. In addition, the short retention time would severely limit production by phytoplankton and zooplankton within the reservoir (i.e., these organisms would be transported through the reservoir prior to completion of their life cycles). Due to the aforementioned factors, the fish populations in the reservoir would be dependent primarily on food organisms entering from upstream impoundments situated on the Columbia and Kootenay rivers. Zoobenthic organisms produced in the reservoir would contribute to the diet of reservoir fish stocks; however, due to the detrimental effects of annual drawdown (operating Regime 1) and daily water level fluctuation (Regimes 1 and 2) on zoobenthos production (see previous zoobenthos discussion), it is felt that the phytoplankton and zooplankton entering from the two upstream reservoirs would be the major food source for fish in the Murphy Creek reservoir.

A number of methods have been used to estimate potential fish yields in natural lakes and reservoirs (Rounsefell 1946; Rawson 1952, 1955; Ryder 1965; Jenkins 1967, 1970; Henderson et al. 1973; Ryder et al. 1974). Many of these are based on the morphoedaphic index (MEI) which is the ratio of total

dissolved solids to mean depth of the waterbody (Ryder 1965). The regression equations relating MEI to fish production assume that the majority of the production occurs *in situ*; that is, the flushing rate is not excessive. Since the hydraulic retention time in the Murphy Creek reservoir generally would be less than 1 day, it is felt that production estimates based on these regression equations would be unsuitable for the Murphy Creek reservoir. Few studies have been conducted on fish production in north-temperature reservoirs, especially reservoirs with low water retention time. For this reason, it is not possible to predict with accuracy the probable level of fish production in the reservoir.

4.4.6 RESERVOIR FISH SPECIES COMPOSITION AND ABUNDANCE

Due to the complex interrelationships between biotic and abiotic factors in a newly formed reservoir, and the competition between species and within a species for the available habitat and food resources, it is not possible to make precise projections about species composition and relative abundance. Due to the paucity of information regarding the responses of major fish species to impoundments in north-temperate areas, predictions are based primarily on knowledge of the environmental requirements of individual species, the probable abiotic and biotic conditions which would be present or develop in the reservoir, and professional judgement. The assessment of the probable fish species composition and relative abundance in the Murphy Creek reservoir is given below. These predictions are based, except where noted, on what would likely happen under post-impoundment conditions with no artificial manipulation (i.e., no stocking of the reservoir or fisheries enhancement).

4.4.6.1 Kokanee

Kokanee are an important sport fish in the Columbia River. In most systems, kokanee are a lake dwelling species, only moving into rivers to spawn during their last year of life. Based on available information, it appears that the majority of the kokanee present in the Columbia River between the Hugh Keenleyside Dam and the Castlegar ferry crossing have

entered the study area from the Arrow Lakes Reservoir. Due to the slow current velocity in the upper section of the Columbia River in the study area, and the abundant food supply (i.e., mysids and zooplankton being swept out of Arrow Lakes Reservoir), this section of the river provides suitable feeding habitat for kokanee.

After inundation the amount of lentic habitat would be increased substantially, thereby expanding the amount of feeding and rearing habitat suitable for kokanee. However, the number of kokanee entering the reservoir from upstream would be the same as would enter the existing river. Similarly, the primary source of food for this species would continue to be zooplankton (including *Mysis*) entering from upstream reservoirs. Since the rate of exploitation of this food source at the present time is not known, it is difficult to predict if additional kokanee could be produced in the reservoir (i.e., if kokanee can increase their utilization of zooplankton in the reservoir environment relative to the river then their production would increase).

Spawning habitat within the reservoir would be limited; only a short section of Norns Creek suitable for salmonid spawning would remain after inundation. Since the kokanee arising from Arrow Lakes Reservoir likely have not historically spawned in Norns Creek, it is not known if a population residing in the reservoir would spawn in the short, unimpounded section of this creek.

If fish passage facilities were incorporated in the dam and fish passage is provided during the construction period, the stocks of kokanee that traditionally migrate upstream from Lake Roosevelt to spawn in Norns Creek (i.e., up to 5000 fish) may be retained at a reduced level (i.e., since only about 38% of the accessible portion of the creek would not be flooded). When the fry emerge from the gravel and move downstream, some may reside in the reservoir rather than migrating downstream to Lake Roosevelt as it is presumed they do at the present time; however, due to the high current velocity through the reservoir relative to most lakes, it is probable that a high proportion of the fry would be transported out of the reservoir.

Based on the information available, it is likely that the kokanee population in the proposed impoundment would be similar or perhaps slightly

larger than the resident population (i.e., excluding the kokanee from Lake Roosevelt) that would occur in the river, were the project not to proceed. This is based primarily on the assumption that both the recruitment of resident kokanee and the abundance of the major food source would be similar both with and without the project (i.e., both arise primarily from Arrow Lakes).

Since the greatest concentration of food organisms would be located just below the Hugh Keenleyside Dam, it is expected that the greatest numbers of kokanee, and therefore the sport fishery for this species, would occur in the upper part of the reservoir. Kokanee are known to undergo wide annual fluctuations in abundance in both Kootenay Lake and Arrow Lakes Reservoir (H. Andrusak, pers. comm.). As a result of variations in kokanee abundance in Arrow Lakes Reservoir, the abundance of this species in the Murphy Creek reservoir also would likely fluctuate.

4.4.6.2 Rainbow Trout

At the present time, rainbow trout are the most sought after sport fish in the study area. The angler catch rate is high (for a large river system), averaging 0.18 fish/rod hour (range = 0.05 to 0.49 fish/rod hour) during a creel survey conducted during the May to October 1980 and March to May 1981 periods (B.C. Fish and Wildlife Branch 1981).

Impoundment of the Columbia River in the study area is expected to severely reduce rainbow trout populations. Based on a NOL of el. 424 m, about 39% of the total accessible length of tributaries would be inundated, severely limiting availability of suitable spawning and rearing habitat for this species. Approximately 62% of the accessible length of Norns Creek, the most important tributary for spawning for this species, would be flooded at a NOL of el. 424 m. Using the Habitat Evaluation Procedure, it was estimated that 73% of the Habitat Units (HU's) available in this stream for spawning would be inundated at this flood level (see Table 4.3).

Rainbow trout deposit their eggs in the surface layer of gravel. The eggs require a constant percolation of water through the substrate to supply oxygen to the eggs and developing fry, and to remove metabolic wastes

(McNeil and Ahnell 1964; McNeil 1966). Under operating Regime 1, the January to June drawdown period includes the time in which rainbow trout spawn; as a result, rainbow trout may spawn in the lower sections of their traditional spawning streams. Upon refilling of the reservoir during the April to June period, the lower parts of the tributary streams would experience reduced current velocities and possibly increased siltation. These factors would reduce the rate of water flow through the gravel, thereby reducing habitat suitability. Siltation also can block the egress of fry from the gravels and reduce available cover (Koski 1966; Hall and Lantz 1969). The overall effect of the development would be a substantial decrease in recruitment of young rainbow trout into the population (i.e., due to reduced spawning and rearing habitat and decreased egg-to-fry survival).

Impoundment of the Columbia River within the study area also would severely affect the abundance of aquatic insects (i.e., mayflies, stoneflies, caddisflies), which likely are the major sources of food for rainbow trout in the Columbia River below the ferry crossing (i.e., above this point, mysids and other zooplankton likely are more important). This would result in reduced abundance and decreased growth rate of rainbow trout in the reservoir.

Rainbow trout could adapt to the post-impoundment lentic environment provided that suitable spawning habitat and adequate food sources are available. This species is a major sport fish in Kootenay Lake (Andrusak and Crowley 1976) and in Upper Arrow Lake (Lindsay 1978). However, due primarily to (1) the detrimental effects of seasonal drawdown (Regime 1) and daily reservoir level fluctuation on zoobenthos production, (2) the substantial loss of spawning habitat, and (3) the blockage of a substantial portion of the adult spawners at the damsite (assuming no passage facilities), it is felt that the rainbow trout population in the reservoir would be substantially less than the population present in the river, even though the amount of aquatic habitat would be increased.

4.4.6.3 Dolly Varden

Available information indicates that only limited Dolly Varden recruitment occurs within the study area. Norns Creek appears suitable for spawning, but no adults were observed during the probable spawning period (August to September) in 1980 and no young-of-the-year or 1-year-old Dolly Varden were captured in the study area. It is likely that the Dolly Varden populations contributing to the sport fishery in the study area are either the remnants of a larger population that migrated up the Columbia River to spawn in tributaries upstream of the Hugh Keenleyside Dam, or else fish that have been transported over the dam into the study area.

The number of Dolly Varden undertaking upstream movements past the proposed Murphy Creek damsite is unknown; however, based on the low overall abundance of Dolly Varden in the study area, it likely is small. A specimen that was tagged immediately below the Hugh Keenleyside Dam in May of 1980 was recaptured at the same site in August 1980 and again in March 1981. This suggests that movements of this species within the study area may be limited.

The overall impact of the Murphy Creek Project on Dolly Varden is expected to be small. The population that would develop in the reservoir likely would be slightly smaller than that presently residing in the river. Since the primary source of recruitment of young into the population would be from the Arrow Lakes Reservoir, population levels in the Murphy Creek reservoir should be directly related to the abundance of this species in the Arrow Lakes Reservoir.

Dolly Varden are extremely vulnerable to angling, a fact which could limit their success in the Murphy Creek reservoir. Nelson (1962) noted that the major factors in the decline of Dolly Varden numbers in the Kananaskis reservoirs were the high vulnerability to capture and the relatively large size and old age at maturity. This resulted in the fish being harvested before they reproduced.

4.4.6.4 Walleye

The effect of the Murphy Creek Project on walleye is difficult to predict since the species has only recently become established in the area. Since walleye fry are poor swimmers (Houde and Forney 1970), any fry that presently may be produced in the study area likely would be carried downstream by the swift current of the Columbia River to Lake Roosevelt. As a result, it is doubtful that walleye would be present in the reservoir area at the time of filling in sufficient numbers to create a self-sustaining population in the reservoir.

Habitat available in the Murphy Creek reservoir should be suitable to support a walleye population if recruitment was supplemented. Young walleye feed primarily on phytoplankton and zooplankton (Hohn 1966; Houde 1967; Paulus 1969; Priegel 1970). In the Murphy Creek reservoir juvenile walleye would have an adequate source of food entering from upstream impoundments. The older juveniles and adults are generalized predators (Scott and Crossman 1973; Machniak 1975b), and an adequate food supply should be available in the reservoir (e.g., young trout, suckers, northern squawfish, etc.). Suitable spawning areas would be available since walleye spawn in a variety of habitats including riprap (large boulders) on the face of dams (Grinstead 1971), rocky shoals in lakes, and in white water below impassable falls and dams (Scott and Crossman 1973). Since the incubation time is short, generally 10 to 19 days at temperatures of 10° to 15°C (Colby et al. 1979), operation of the project under Regime 1 (i.e., refilling of the reservoir in the April to June period) would not affect egg incubation in most years. The extent of transport of walleye fry out of the reservoir by the current is not known, but it certainly could limit the abundance of this species in the reservoir.

4.4.6.5 Lake Whitefish

It is possible that the lake whitefish population would be slightly larger in the proposed reservoir in comparison to the present river population. Since this species is typically a lake dwelling species, it should react positively to an increase in lentic habitat. Lake whitefish presently are found only in low

numbers in the study area, their distribution primarily being restricted to the slow water section of the river upstream of the ferry crossing.

Production of lake whitefish in the Murphy Creek reservoir would be limited primarily by recruitment. In lakes, this species usually spawns in shallow water over gravel, sand, or cobble substrates (Hart 1930; Bidgood 1973; Ash 1974). Since lake whitefish are fall spawners, incubation occurs through the winter period. A drawdown during the January to June period (under Regime 1) probably would result in dessication or freezing of the majority of the eggs. Similarly, the daily water level fluctuation of up to 2.0 m in the March to May period likely would prevent successful incubation of any eggs spawned in shallow (less than 2.0 m) areas under Regime 2. Although lake whitefish also have been reported to spawn in streams (Bajkov 1930; Fabricius 1950; McLeod et al. 1978), the tributaries to the Murphy Creek reservoir likely would be unsuitable due to small size and limited flows throughout the winter.

In summary, the habitat conditions in the Murphy Creek reservoir should be more favourable than the present river for adult or juvenile lake whitefish entering the system from the Arrow Lakes Reservoir. However, spawning habitat within the reservoir likely would be restricted due to annual drawdown or daily water level fluctuation. Lake whitefish, therefore, are not expected to successfully reproduce in the reservoir while the project is operated under Regime 1, and successful reproduction in the reservoir under operating Regime 2 is expected to be limited to some extent by the daily water level fluctuations.

4.4.6.6 Mountain Whitefish

It is expected that mountain whitefish would be less numerous in the reservoir than in the present riverine system. Although Nelson (1965) indicated that mountain whitefish populations showed no sign of being unfavourably affected by hydroelectric development, Gangmark and Fulton (1949) and Earnest et al. (1966) reported the near disappearance of this species from the section of the Columbia River impounded by the Grand Coulee Dam.

Since mountain whitefish are traditionally late fall or early winter spawners, they would be adversely affected by the drawdown (Regime 1) and the daily water level fluctuation in the reservoir. Mountain whitefish generally spawn in shallow riffles over cobble or gravel in streams (Brown 1952; Thompson 1974; McLeod et al. 1978; Renewable Resources Consulting Services Ltd. 1978); however, some authors have observed this species spawning in lakes over rock or cobble substrates (McAffee 1966; Hagen 1970). Unless mountain whitefish are able to use non-flooded sections of reservoir tributaries such as Norns Creek and Champion Creek, reproductive success would be low. Under operating Regime 1, eggs that are deposited in shallow areas within the drawdown zone would be subject to high mortality when the water level is reduced. Since ripe fish (males and females) were noted in the Columbia River within the study area during late January 1981, at least a portion of the population may spawn after reservoir drawdown. Egg-to-fry survival would be greater for eggs spawned at that time.

The primary food of mountain whitefish is generally benthic organisms, especially immature insects (Nelson 1965; Scott and Crossman 1973); however, they also are known to feed on other aquatic invertebrates including zooplankton (Godfrey 1955; Renewable Resources Consulting Services Ltd. 1974, 1978). Godfrey (1955) noted that in shallow lakes in the Skeena River system, mountain whitefish were usually less abundant in lakes where the adults were heavily dependent on midwater plankton. Since zoobenthic production in the Murphy Creek reservoir is expected to be relatively low (due primarily to drawdown and daily water level fluctuation), it follows that mountain whitefish would be dependent primarily on zooplankton produced in upstream-situated impoundments. Since other species of fish are better adapted to zooplankton feeding (i.e., kokanee, lake whitefish), interspecific competition for food likely would limit the size of the population and growth rate of mountain whitefish in the reservoir.

4.4.6.7 Burbot

Burbot are expected to occur in moderate numbers in the Murphy Creek reservoir. Since burbot are a mid-winter spawner (Carl et al. 1977), at least

a portion of the spawning likely would occur after drawdown (Regime 1) has taken place. Food for adult burbot in the reservoir should be abundant since they are primarily piscivorous. Food for the young may be somewhat limited since juvenile burbot normally feed on aquatic insects and molluscs, although in some areas mysids are heavily preyed upon (Scott and Crossman 1973).

4.4.6.8 Sturgeon

Sturgeon would likely be absent from the Murphy Creek reservoir, or at best would occur only in very low numbers. The movements of sturgeon in this system have not been defined but sturgeon are known to undertake fairly extensive movements in other systems. H. Andrusak (pers. comm.) has noted movements of 100 to 160 km in the Kootenay River system between Creston, B.C. and Kootenai Falls, Montana. Sturgeon in the Columbia River may undertake movements between Lake Roosevelt and the upper locations in the study area. If movements of this magnitude occur annually, then it is probable that upstream movement would be blocked during dam construction. The extent to which sturgeon would use fish passage facilities is unknown; however, since sturgeon are bottom-dwelling fish, it is doubtful they would utilize a fishway. Poddubny (1971) noted that the Volga sturgeon in the USSR used a fish lift at a hydroelectric dam. Malinin et al. (1972), however, noted that none of the 16 sturgeon that were radio tagged in the Volga River below the Saratov Hydroelectric Station moved into a fish elevator entrance.

It is not known if sturgeon reproduce in the study area; however, since spawning generally occurs "over rocky bottom in swift currents near rapids or waterfalls" (Scott and Crossman 1973), sturgeon may spawn in the section of the Kootenay River below the Brilliant Dam or possibly immediately below the Hugh Keenleyside Dam. Impoundment of these areas would probably reduce their suitability for spawning.

4.4.6.9 Suckers (*Catostomus catostomus*, *C. macrocheilus*, *C. columbianus*)

Large populations of suckers likely would develop in the Murphy Creek reservoir since most catostomids are able to adapt to a wide range of habitat conditions. Posewitz (1962) reported that suckers made up 84% of the gill

net catch in an impoundment of a tributary to the Missouri River. Liek (1978) noted that white and longnose suckers contributed 88.5% and 8.2%, respectively, to the gill net catch in another Missouri River reservoir. In Lake Roosevelt, suckers accounted for 7.2% of the catch in 1948 (Gangmark and Fulton 1949) and 19.2% of the catch in 1962-63 (Earnest et al. 1966).

Suckers appear able to adapt to conditions in reservoirs, even in those with large annual drawdowns. They are spring or early summer spawners and their eggs generally hatch in about 2 weeks (Geen et al. 1966). Most species spawn over gravels in streams or rivers, or on gravelly or sandy shoals in lakes. Due to the short incubation period for the eggs and the nonspecific substrate requirement for this group of species, their reproductive success likely would not be seriously affected by the proposed reservoir operating regimes.

The relative abundance of each of the sucker species after impoundment is difficult to predict; however, due to greater abundance of the largescale sucker in the study area at the present time, it would probably be the dominant species in the reservoir. Since the bridgelip sucker was scarce in the study area and apparently moved into the region to spawn, it is expected to be scarce or absent in the reservoir on the assumption that upstream migration would be blocked by the dam.

4.4.6.10 Other Non Sport Species

On the basis of collections in the present study and observations by locals (B. Salekin, pers. comm.), carp are apparently present in the area only during spring and summer. Hence, it is probable that this species migrates into the study area from Lake Roosevelt where it has been reported to be abundant (Earnest et al. 1966). If this is the case, their movements into the study area would be blocked unless suitable fish passage facilities are provided.

Habitat conditions in the reservoir likely would not be conducive to carp reproduction, especially while the project is operated under Regime 1. Carp reportedly spawn in areas of dense aquatic macrophytes (Swee and McCrimmon 1966) and, due to the effects of annual drawdown (Regime 1)

and daily water level fluctuation, few areas of aquatic macrophyte growths are expected in the reservoir.

Populations of peamouth, redbase shiner, and northern squawfish are expected to be high in the reservoir. Nelson (1974) noted large populations of these species in Williston Lake. Earnest et al. (1966) reported that peamouth, northern squawfish, and redbase shiner contributed 46.3%, 25.6%, and 1.0% to the gill net catch in Lake Roosevelt. The low numbers of redbase shiner likely reflect the inefficiency of the sampling method (gill nets) for collecting this species.

It is expected that the large populations of cyprinid species would compete with sport fish such as kokanee, rainbow trout, and whitefish for the available food supply. This may reduce the capacity of the reservoir to support sport fish; however, the cyprinids also would constitute an abundant source of prey for the piscivorous species such as rainbow trout and Dolly Varden. The predatory nature of northern squawfish may result in some losses of juveniles of the important sport fish.

4.4.6.11 Summary of the Probable Post Impoundment Fishery Resource

- (1) Kokanee numbers in the reservoir are expected to be similar to numbers of resident kokanee in the area were the project not to proceed; however, kokanee may increase slightly in abundance in response to an increase in lentic type habitat. Recruitment would be limited primarily to influx of fish from the Arrow Lakes Reservoir. Due to the input of the primary food source (i.e., zooplankton including mysids) at the Hugh Keenleyside Dam, this species would probably be most abundant in the upper end of the reservoir. During the drawdown period expected under operating Regime 1, this species would be concentrated in the section of the river above the ferry crossing which would provide habitat most similar to their preferred habitat in the existing river. If the fish disperse throughout the reservoir when it is at normal operating level, high losses of fish through the turbines at the Murphy Creek dam may occur, especially during

periods of high flow releases (e.g., during active drawdown of the reservoir).

- (2) Rainbow trout numbers are expected to decrease substantially due to loss of much of the prime spawning and rearing habitat, and due to expected decreases in food abundance. It is unlikely that the reservoir would produce more than half of the numbers of fish produced in the present river system.
- (3) Mountain whitefish are expected to decrease after impoundment due to loss of prime spawning and rearing habitat, reduction in preferred food abundance, and competition with other sport and coarse fish species.
- (4) Walleye are not expected to establish in the reservoir due to blockage of upstream spawning migrations (assuming suitable fish passage facilities are not provided) and probable loss of fry if this species did spawn in the reservoir (i.e., fry would be carried out of the reservoir).
- (5) Dolly Varden are expected to occur in the reservoir in low numbers, since population recruitment will be restricted primarily to those fish that enter the reservoir from the Arrow Lakes system.
- (6) Burbot likely would be present in moderate numbers in the reservoir.
- (7) Coarse fish such as suckers, northern squawfish, peamouth, and reidside shiners likely would exhibit increased populations in the reservoir. They may compete with some of the sport fish species for available food and space; however, they also would become a source of prey for the piscivorous species of fish.
- (8) Angler catch rates for kokanee in the reservoir likely would be similar to present levels; however, catch rates may decline slightly due to dispersion of the population in a larger volume of water. Since the abundance of kokanee appears to fluctuate widely from year to year in this system (also in the Arrow Lakes

Reservoir and Kootenay Lake), the catch rates for kokanee in the reservoir likely also would vary from year to year.

Catch rates for rainbow trout likely would decrease substantially in the reservoir compared to the present river. Based on the extent of loss of spawning and rearing habitat within the system, and the likely dispersion of the available fish in the greater water volume, a very rough estimate of the probable angler success rate would be about 20% of the present success, based on a similar fishing pressure. It must be strongly emphasized, however, that due to the limited amount of data available and due to the complex factors controlling biological populations and their responses to environmental perturbations, the precision of the predicted angler success rate may be low.

4.4.7 DOWNSTREAM EFFECTS

The Murphy Creek Project would affect the aquatic resources downstream of the project damsite only to a limited degree. The major effects would be related to the development of a tailwater fishery, and to reduction in dissolved gas saturation levels.

4.4.7.1 Development of a Tailwater Fishery

As discussed in previous sections, the placement of a dam on the Columbia River slightly upstream of Trail would block upstream movements of fish species that annually undertake movements in the Columbia River for feeding or spawning purposes. Most sport fish species likely would be affected. In addition, the transport of water through the reservoir, particularly during drawdown (operating Regime 1), would undoubtedly result in a loss of large numbers of newly hatched fry or juveniles (and possibly adults) from the reservoir. Although some mortality would occur as fish pass through the turbines (likely 5 to 10%), the surviving individuals would populate the river below the dam. This likely would result in concentrations of sport fish in the section of the river below the dam, and may thereby enhance the sport fishery in this area. Improved sport fisheries often develop in the tailwater areas of dams (Pfitzer 1967; Walberg et al. 1971; May 1973).

It is probable, therefore, that the sport fishery in the Columbia River near Trail would increase substantially during the first few years after impoundment. The extent of this fishery in later years would be dependent on the production of fish in the Murphy Creek reservoir. Since most of the stream spawning habitat for rainbow trout, the main sport fish in the area, is presently located upstream of the proposed damsite, blockage of their spawning runs would decrease the recruitment of their progeny to the fishery. This may result in a long-term decline of rainbow trout in downstream areas.

4.4.7.2 Dissolved Gas Supersaturation

As mentioned in Section 3.1.1.1 of this report, total dissolved gas levels in the Columbia River within the study area presently are high throughout much of the year due to effects of upstream impoundments. The concentrations of dissolved gas are high enough to potentially cause fish mortality or to restrict the use of the available aquatic habitat (i.e., the fish must remain in deep water to avoid gas bubble disease problems). The Murphy Creek Project is expected to substantially decrease total dissolved gas concentrations in the Columbia River. This would have a beneficial effect on fish populations both within the potential reservoir area and in the Columbia River downstream of the Murphy Creek dam.

4.4.7.3 Other Downstream Effects

Since the Murphy Creek reservoir would be subject to daily water level fluctuations of up to 2.0 m in the March to May period, and up to 1.5 m in other months, it is expected that downstream flow variation will be substantially greater than occurs under present conditions. Daily fluctuations of tailwater level at the dam for operational purposes would be limited to 3.0 m with an hourly variation limited to 1.0 m (B.C. Hydro 1982). Large daily variations in flow and tailwater levels would have a detrimental effect on downstream benthic production, and would reduce the suitability of the area for fish rearing. Under Regime 1, increased flows downstream of the dam may occur during the active drawdown of the reservoir; however, if draw-down is staged over a period of a few days, the effects on the downstream

aquatic resources should be small. Similarly, reduced flows can be expected during the short period of reservoir filling.

No significant changes in thermal regime have been predicted for the outflow of the reservoir in comparison to the present river (IEC 1981).

5.0 MITIGATION AND COMPENSATION OPPORTUNITIES

5.1 CONSTRUCTION PHASE

5.1.1 BLOCKAGE OF MIGRATIONS

During the construction of the Murphy Creek dam, upstream movements of fish would be blocked. In order to maintain populations of these species within the reservoir, it may be necessary to ensure passage during the construction period. If obvious blockages of fish migrations occur as a result of channel constriction during the initial phases of construction, temporary fish passage facilities or structures to reduce velocity and provide resting areas (e.g., large rocks, groins, or baffles) should be installed along the east bank of the river. During later stages of construction when the complete river flow is passed through the spillway, trapping and trucking the fish around the damsite may be the only feasible method of ensuring fish passage.

The extent to which effort or funds should be expended to ensure fish passage during the construction period will be dependent on the management plan development for the reservoir. Passage of fish during the construction period would be of less benefit if permanent fish passage facilities are not incorporated into the dam.

5.1.2 SEDIMENT LOADS

Strict precautions should be taken to ensure that sediment input to tributaries and the Columbia River would be minimized during the construction period. Methods to reduce sediment inflow include riprapping unstable slopes, use of rock material rather than soil for fill, and control of erosion on slopes by seeding or mulching, or by the use of blankets, or binders. Wherever possible, borrow pits should be located well away from active stream channels. Runoff or effluents which have high suspended sediment concentrations (e.g., gravel washing operations) should be diverted to settling or filter ponds.

Settling ponds should be dredged when necessary, and the sediment removed to an appropriate disposal site. To ensure that adequate precautions are taken to control erosion and the input of sediment into the aquatic

system, strict guidelines should be written into the construction contracts. An environmental inspector should be present onsite during the construction period to ensure that the guidelines are followed.

5.1.3 WATER QUALITY

Spills or discharges of waste materials such as cement, gas, oils, greases, salts, sewage, and chemicals could affect the water quality downstream of the construction site. To ensure that deleterious materials that may affect fish and other aquatic life do not enter the watercourse, strict guidelines and regulations relating to storage and disposal methods should be an integral part of construction contracts. Also, contingency plans in the event of a spill should be prepared and agreed upon by the contractors prior to beginning construction. All fuel storage areas, vehicle service areas, and construction camps should be located well away from river or tributary streams. An environmental inspector should be onsite during the construction period to ensure the guidelines are followed.

5.1.4 USE OF EXPLOSIVES

The use of underwater explosives could result in high mortalities to fish, especially if fish are concentrated in the area due to migration blockage. Whenever feasible, excavation using explosives should be conducted "in the dry." Where the use of underwater explosives is necessary, precautions should be taken to minimize the effects on fish. The seasonal timing of underwater blasting should be such that periods of peak fish migration (i.e., early spring and mid-August) are avoided. If monitoring indicates that fish are abundant in the vicinity of the blasting site, then the following precautions should be taken to minimize mortality (Renewable Resources Consulting Services Ltd. 1978): (1) burying the charge as deep as possible into the substrate; (2) staging major detonations in a series of successive charges with a time lag in between firings to allow dissipation of most of the shock wave; and (3) dispersing concentrations of fish that may be in the area by use of sonic or electric shock.

5.1.5 RESERVOIR CLEARING

Clearing of trees from the reservoir prior to inundation is recommended in order to minimize debris problems, improve navigation, and to maintain aesthetic values in the reservoir. If trees are present in the deeper part of the proposed reservoir area (i.e., below the expected drawdown level), the stumps should be left in place to provide a colonization substrate for benthic algae and invertebrates, and to provide cover for fish after inundation.

To reduce the potential effects of erosion on the cleared areas, preclearing should be conducted immediately prior to inundation. If it is necessary to clear one or more years prior to flooding, the cleared areas should be seeded with a cover crop to reduce erosion.

5.1.6 INCREASED ANGLING

During the construction period, the angling pressure exerted by the project staff should be monitored. If it is evident that fish stocks are being depleted by anglers (especially if fish stocks are concentrating below the project site), then it would be necessary to identify the problem to the B.C. Fish and Wildlife Branch so that they may implement appropriate management measures (e.g., specific area and season closures near the construction site; reduction of catch limit).

5.1.7 TIMING OF RESERVOIR FILLING

The optimal timing for reservoir filling would be after the emergence of rainbow trout from the gravel in July and prior to spawning of fall spawning species (i.e., end of August). This would allow successful spawning and incubation of rainbow trout during the year of filling, and provide the least interference with reproduction by fall spawners.

5.2 OPERATIONAL PHASE

5.2.1 BLOCKAGE OF FISH MIGRATIONS

To reduce the effects of the Murphy Creek dam on upstream fish migrations, fish passage facilities could be incorporated into the design of the

dam. There are three basic methods that have been used successfully to pass fish; these are:

- (1) conventional fishways;
- (2) trapping and trucking (elevators); and
- (3) fish locks.

Several types of fishways have been developed to facilitate passage of fish over hydroelectric dams. Descriptions of various designs are presented by Clay (1961), Ziemer (1962), and Bell (1973). Murray (1976) reviewed the literature and costs of fishways for possible implementation on the Revelstoke project. It is not possible to accurately estimate the cost of a fishway for the Murphy Creek Project at this time since cost will be dependent on the design chosen, the engineering constraints involved in the incorporation of a specific design into the dam, and the actual time of construction. However, a crude approximation of costs was made on the basis of several assumptions. The cost figures provided by Clay (1961) were extrapolated to 1981 costs using Canadian Construction Price Indices. It was assumed that fishway costs would be a minimum of 240% higher than the 1956 costs. An example of the costs of a small pool-type fishway that may be suitable for the Murphy Creek project would be as follows:

Design and Cost Assumptions

Volume each pool = $1.8 \text{ m} \times 1.2 \text{ m} \times 2.4 \text{ m} = 5.2 \text{ m}^3$

No. Pools Required (assuming 0.3-m head between pools) = 47

Total Volume of Pools = 244 m^3

Length of Powerhouse = 155 m

Cost/ m^3 = $\$229/\text{m}^3$ (in 1956 dollars) $\times$ 240% = $\$550/\text{m}^3$

Cost Calculations

Basic cost of fishway = $244 \text{ m}^3 \times \$550/\text{m}^3$ =	\$134 200
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Cost of Entrance/Exit Appurtenances (29% of fishway) =	38 900
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Auxiliary water supply (80% of fishway) =	107 400
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Powerhouse collection system (155 m $\times$ \$17 400/m) =	<u>2 697 000</u>
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Estimated Total Cost = \$3.0 million (1981 dollars)

Additional costs would be incurred for water supply and fishway exits in order to allow operation of the structure during the period when the reservoir was drawn down.

In order to ensure that the above preliminary estimate was in the right order of magnitude, personnel of Fisheries and Oceans Canada were contacted to obtain an up-to-date "rule-of-thumb" cost estimate for a fishway. The figure that is presently used for smaller vertical slot type fishways (e.g., Kakweiken River fishway) is \$25 000 per 0.3-m rise in elevation (J. McNally, Fisheries and Oceans Canada, Vancouver, pers. comm.). It was noted, however, that site-specific costs may vary greatly depending on access, collection facilities, size of runs, etc. Using this figure, a preliminary cost estimate of a fishway (14-m rise in water level) for the Murphy Creek dam would be about \$1.2 million. However, additional costs specific to the dam (i.e., collection facilities) and operating regime of the reservoir likely would add substantially to this figure.

The fishway cost estimates provided should be used only to give an indication of the order of magnitude of the cost involved. For more detailed costing, discussions with B.C. Hydro engineers would be required to determine the design most suitable for the facility, and the site-specific costs.

Fish elevators, which include any mechanical device for transporting fish upstream over a dam (e.g., trapping and trucking, bucket and cable systems, etc.) have been utilized successfully in both Europe and North America. The most common example of this method as used in Canada and the United States has been trapping fish in the tailwater area and trucking them over the dam. Clay (1961) cites examples of these operations at the Mud Mountain Dam and the Baker Dam in Washington State, and at the Cleveland Dam near Vancouver, B.C. He indicates that these trapping and trucking operations are the only reasonable means of providing adult fish passage where there is a combination of an extremely high dam, and a comparatively small run of fish.

Another potential mechanism for passing fish over the dam would be utilization of a fish lock. The lock functions by allowing fish to enter a chamber, at tailwater level or from a short fishway, then raising the water

level until fish can swim into the forebay or reservoir above the dam. These devices have undergone only limited testing in North America although they are in widespread use in Europe (Clay 1961). The major advantages of fish lock over passage facilities using a trapping and trucking operation are: (1) the lower capital cost for low head dams (less than 18 m); (2) the lower operating cost; and (3) the ability to be used for the transport of downstream migrants (e.g., adults and juveniles). Disadvantages include greater possibilities for delay and injury. Clay (1961) gives details relating to the design of various fish locks including the Borland fish lock, which is one of the more popular designs. The water requirement for a Borland lock is low, generally around $0.7 \text{ m}^3/\text{s}$. Using the cost data provided by Clay (1961), a very rough estimate for a single fish lock for the Murphy Creek dam would be \$0.6 to \$0.75 million (1981 dollars). Due to the large annual drawdown in the reservoir under operating Regime 1, either a second lock, or a more expensive structure using a multiple outlet, would be required. This would bring the total cost up to \$1.0 to \$1.5 million.

The net benefit of incorporation of fish passage facilities into the dam cannot be predicted at the present time. The Murphy Creek reservoir at a normal operating level of el. 424 m would inundate approximately 62% of the accessible length of Norns Creek, the major kokanee and rainbow trout spawning stream in the study area. This, however, would still leave one of the prime spawning sections in the creek. Although the reservoir would reduce the spawning capacity of the creek by about 70%, fish passage facilities may be justifiable in order to maintain a reduced run of perhaps 1000 to 2000 kokanee, and 125 to 200 rainbow trout. Flooding to elevation 424 m would inundate approximately 39% of the total length of tributary streams used by rainbow trout for spawning and rearing.

In summary, consideration should be given to the incorporation of fish passage facilities into the design of the Murphy Creek dam. Since little information is available relating to the numbers of sport fish that move past the damsite, it is not possible at the present time to assess the cost/benefit ratio of this mitigation option. Discussions with the B.C. Fish and Wildlife Branch would be required to determine the most suitable management plan

for the reservoir and, related to this, the requirements for fish passage facilities.

The question has been raised as to the possibility of incorporation of fish passage facilities into a boat lock at the dam. Although such a structure may allow the passage of some fish, its overall success likely would be low unless consideration is given at the design stage to factors for the attraction of fish into the lock, passage out of the lock, and to the automatic operation of the facility to pass fish without undue delay. If a boat lock is included in the dam, the potential for combining it with fish passage facilities should be given further consideration.

5.2.2 PROVISION OF COVER

The provision of artificial cover for fish in the reservoir would have two major advantages: it would provide hiding places for juvenile fish (and thus allow them to avoid predation), and it likely would concentrate adult fish and improve angling efficiency. During clearing of the reservoir, some areas at the lower end of the reservoir below the drawdown level (operating Regime 1) should be left with tall stumps. After flooding, artificial shelters constructed of used automobile tires or brush bundles may be suitable for use in the reservoir, again depending on the overall management scheme for the reservoir. Both tire and brush shelters have been utilized successfully to supplement natural cover and feeding habitat in reservoirs in the United States (Vogele and Rainwater 1975; Prince and Maughan 1978; Stone 1978). These structures have the advantage of low capital cost (i.e., about \$25 to \$100/brush shelter in 1977 dollars) and a low maintenance cost (\$4 to \$5/year/brush shelter) (Nelson et al. 1978). Prince and Maughan (1978) cite the construction of a tire reef (9500 m²) at a cost of about \$5000. The major potential disadvantage of these shelters is their hazard to navigation unless anchored in deep water (i.e., below the drawdown level).

5.2.3 RATE OF DRAWDOWN (OPERATING REGIME 1)

To minimize the stranding of juvenile fish and fish food organisms inhabiting shallow regions, the Murphy Creek reservoir, when operated under

Regime 1, should be drawn down gradually. This would maximize the ability of the juvenile fish and aquatic insects to move with the receding water levels. Although a slow drawdown rate protects juvenile fish and invertebrates, it is desirable to achieve the maximum drawdown prior to burbot spawning in mid-winter. As a preliminary recommendation, a maximum drawdown rate of 0.5 m/day is suggested as a compromise between operational requirements, juvenile fish and aquatic organisms' protection, and the requirement for mid-winter spawning protection (e.g., burbot spawning). The preferable rate of drawdown may vary from year to year depending on the specific timing requirements of the drawdown (i.e., if drawdown is necessary in January, the rate may be different than for drawdown in late March). The rate of refilling of the reservoir is less critical, but it would probably be most beneficial to fill the reservoir as fast as possible (assuming adequate downstream releases are maintained from the dam) in order to reach stable conditions in the reservoir as early as possible.

5.2.4 HEADPOND LEVEL FLUCTUATIONS

The daily water level fluctuation (i.e., up to 2.0 m) will have a severe detrimental effect on the aquatic organisms and productivity in the reservoir.

To provide more stable conditions for spawning and fry rearing along the shoreline and to enhance benthic production, the daily and weekly variations in headpond level should be minimized (i.e., daily fluctuations of less than 0.3 m would significantly enhance the reservoir for sport fish production). During spawning periods of species which may spawn along the periphery of the reservoir, daily water level fluctuations should be scheduled for minimum levels to occur during the dusk to darkness period. As active spawning often occurs at night for species moving into the shallows, this would tend to limit spawning use to areas below the daily drawdown level and thus reduce exposure and loss of eggs.

5.2.5 RELEASES FROM THE HUGH KEENLEYSIDE DAM

To minimize dissolved gas supersaturation within the Murphy Creek reservoir and downstream areas, water releases at the Hugh Keenleyside Dam should be through the low level ports or turbines whenever possible.

5.2.6 ENHANCEMENT OPPORTUNITIES FOR THE MURPHY CREEK RESERVOIR

Due to the adverse effects of the development on the fisheries resources in the study area, it is likely that some form of enhancement would be required to provide adequate sport fishing opportunities in the reservoir. It is not possible to recommend a specific enhancement plan at the present time, since the most cost-effective measures will be dependent on a number of factors including (1) the period of time during which the reservoir would be operated under Regime 1, (2) the actual physical characteristics that develop in the reservoir after stabilization, (3) the fish populations that develop naturally, and (4) the desired fisheries management plan for the reservoir. Since management of the freshwater fisheries resources within British Columbia is the responsibility of the Fish and Wildlife Branch of the B.C. Ministry of the Environment, the specific enhancement plan should be designed through consultation with this agency.

Following are some of the potential options available for enhancement of the sport fishery in the Murphy Creek reservoir. It should be noted that the following list is not all-inclusive; rather, it includes the most common or most obvious methods available that may be suitable for the reservoir.

Artificial Propagation

- (1) Annual stocking from existing hatcheries.
- (2) Creation of a spawning or incubation channel to increase the reproductive potential for sport fish in the reservoir.
- (3) Provision of an incubation and rearing facility in the project area (i.e., mini-hatchery).

Mechanical Enhancement Techniques

- (1) Facilitated access for fish over natural obstructions within specific tributaries.
- (2) Selective habitat improvements within the remaining accessible portions of tributaries to the reservoir.

The capital and operating costs of a specific enhancement option, and the probable success, will depend on the fish species selected for enhancement and the level of enhancement desired. The two species most suited for enhancement in the study area are rainbow trout and kokanee. Culture techniques are relatively well known for these species through years of hatchery propagation. Also, since rainbow trout are spring spawners and kokanee are fall spawners, one set of propagation facilities can be utilized for both species. For the purposes of providing a very crude estimate of probable costs of various options, it will be assumed that enhancement in the reservoir will be directed toward these two species.

5.2.6.1 Stocking Using Existing Hatcheries

Although stocking of the Murphy Creek reservoir with rainbow trout produced at existing hatcheries was considered as a potential option, it likely would not be feasible due to the present commitments of fish produced at existing British Columbia hatcheries. In addition, use of hatchery stocks rather than indigenous stocks for propagation may reduce the effectiveness or desirability of a stocking program (Vincent 1972; Parkinson and Slaney 1975; Montana Department of Natural Resources and Conservation 1979).

5.2.6.2 Spawning Facilities

Due to the limited spawning habitat that would be available after inundation, a spawning channel is a potential mitigation option. Such a channel duplicates optimum hydraulic and substrate conditions for the production of the target species. The design technology for spawning channels is well developed for anadromous salmon (e.g., Jones Creek, Weaver Creek, Big Qualicum River); however, spawning channels have had limited use in the enhancement of freshwater fisheries. In 1968, a spawning channel for kokanee was constructed on Meadow Creek, a tributary to Kootenay Lake. After some initial problems, the channel proved very successful for the production of kokanee, with egg-to-fry survival rates averaging 11.8% between 1968 and 1975 (Fleck and Andrusak 1977). To maintain a high incubation success rate, however, the channel must be well maintained, with regular cleaning of sediment from the gravel.

Rearing facilities would be required in conjunction with a propagation facility in the study area to ensure that the fry reach a larger size, thereby increasing survival in the reservoir (H. Andrusak, pers. comm.). A fry collection system would be required in a spawning channel to capture the emerging fry, and direct them into rearing ponds or tanks.

The capital cost of a spawning channel depends on the following cost variables: land acquisition, access, road construction, site preparation, gravel extraction, and channel preparation (Murray 1976). The Meadow Creek spawning channel, designed to accommodate 1.5 million spawners, was completed in 1968 at a cost of \$750 000 (B.C. Ministry of the Environment undated information pamphlet). A spawning channel for chinook salmon built at Priest Rapids in Washington cost \$3.4 million, not including land acquisition costs and buildings. Annual maintenance costs were reported to be \$80 600 in 1970 (Allen and Meekin 1973). The major disadvantages of spawning channels are their high capital and operating cost, their high flow requirement, and their requirement for a fairly large area of flat terrain.

Within the Murphy Creek Project area, only one location was identified as being potentially suitable for a spawning channel. This was the terrace along the south side of Champion Creek approximately 0.6 km upstream of its mouth; however, due to variable flows in the creek, a supplementary water supply might be required at this site. Also, access to the site may be difficult. It should be noted that, since kokanee do not appear to spawn in Champion Creek, kokanee egg plants (possibly using eggs stripped from adults from Norns Creek) would be required initially to establish a run into a spawning channel on this stream. Norns Creek, the major tributary utilized by kokanee in the study area, flows through a steep, narrow valley in the section between the reservoir flood level and impassable falls farther upstream; as such, the required land would not be available for a spawning channel.

5.2.6.3 Onsite Incubation and Rearing Facility

The most feasible method of enhancing the sport fishery in the Murphy Creek reservoir appears to be through the use of an onsite "mini-hatchery"

which would be suitable for the incubation of eggs and rearing of fry of both rainbow trout and kokanee. Similar facilities have been utilized for rainbow trout culture at Meadow Creek (Andrusak and Fleck 1976), and at the Peace Canyon project on the Peace River near Hudson Hope. A small hatchery also is currently under construction at Hill Creek on the Arrow Lakes Reservoir.

To ensure a constant supply of high quality water for such a facility, a source of groundwater likely would be required rather than have the facility depend on an existing stream (H. Andrusak, pers. comm.). The facility also should be situated near an existing stream such as Norns Creek which could be used as a source of water and release site for "imprinting" a natal stream on the fish; this is to ensure that the stocked fish return in later years to the natal stream where they could be collected for egg taking.

Based on a facility similar to the one being constructed on Hill Creek, it is estimated that the capital cost of a mini-hatchery for the Murphy Creek reservoir would be approximately \$500 000 (not including land acquisition cost), and would have an annual operating cost of \$80 000 to \$90 000 (in 1981 dollars). The exact location of such a facility would be dependent on the availability of land above the flood level, and the availability of a suitable groundwater source. This type of facility does not require a large parcel of land and the most suitable area likely would be along Norns Creek, provided that a groundwater supply is available.

5.2.7 CONSTRUCTION OF FISH PASSAGE FACILITIES AT NATURAL OBSTRUCTIONS

Most of the tributaries entering the Murphy Creek reservoir have a steep gradient with natural obstructions (i.e., falls or cascades) within a few kilometres of the mouth. In streams entering on the west side of the Columbia River, the highway and/or railroad culverts appear to limit the upstream movement of fish due to velocity or vertical outfall barriers. To increase the potential spawning and rearing habitat available to rainbow trout in the reservoir, consideration could be given to providing access over impassable falls on Norns Creek or Champion Creek. Another option would be to modify highway culverts on streams such as Murphy Creek, China

Creek, or Blueberry Creek to reduce flow velocity and allow passage of rainbow trout. Due to the height of the falls on Norns Creek (i.e., estimated to be 30 to 35 m high), it is not feasible to install a fish passage structure at this site. The steep gradient of upstream reaches of other creeks in the study area likely would limit the value of facilitated access past present blockages.

5.2.8 INSTREAM IMPROVEMENTS

To maximize sport fish production in accessible tributary reaches above the level of inundation, consideration should be given to conducting habitat improvement. Placement of clean, sorted gravels in the stream to increase spawning habitat, or the provision of overhead cover, log deflectors, etc. to provide a greater diversity of habitat, can increase stream production (Shetter et al. 1946; Saunders and Smith 1962; Hunt 1969).

White and Brynildson (1967) provide a good review of available techniques for habitat manipulation. The extent to which these techniques would be suitable for tributaries entering the Murphy Creek reservoir is dependent on the gradient and instream characteristics of the remaining accessible reaches. The capital cost of most instream improvements generally is low (i.e., mainly labour costs); however, maintenance costs can be high over the years, especially in streams subject to wide fluctuations in flow (Nelson et al. 1978).

5.3 ENHANCEMENT OUTSIDE OF THE IMMEDIATE STUDY AREA

Opportunities likely exist for implementing enhancement projects in nearby streams such as the Slocan or Salmo rivers; however, it is unlikely that these alternatives would be well received by residents in the immediate Murphy Creek study area. Stephenson (1981) indicated that by far the majority of the fishing effort in the study area comes from local inhabitants. Also, the creel survey conducted by the B.C. Fish and Wildlife Branch indicated that anglers in the study area had spent an average of only 1.29 hours fishing at the time of interview; this compares to an average time spent fishing in many other areas of 4 hours per day. The low individual angler effort may be due, in part, to many anglers in the area going down to

the river after work rather than driving some distance to fish for the day (Stephenson 1981). Since the fishery on the Columbia River within the study area is primarily a local fishery, Stephenson (1981) predicted that only a small proportion of the angling effort would be transferred out of the study area.

The enhancement potential of the Slocan or Salmo rivers has not been assessed to date (H. Andrusak, pers. comm.). Before a detailed enhancement plan could be developed, a minimum of 2 years of biological studies would be required on these two systems (H. Andrusak, pers. comm.).

Enhancement of the sport fish populations in the Arrow Lakes Reservoir may result in increased recruitment to the sport fish populations in the Murphy Creek reservoir. Available information indicates that a portion of the sport fish population in the Murphy Creek study area has moved into the area from the Arrow Lakes Reservoir, presumably through passage over the spillway or through the low level ports at the Hugh Keenleyside Dam. The B.C. Fish and Wildlife Branch is currently investigating the design of fish passage facilities on the Inonoaklin River which would substantially increase kokanee and rainbow trout spawning habitat for the Arrow Lakes Reservoir. Other enhancement opportunities likely exist for the Arrow Lakes Reservoir (e.g., spawning channel at Renata), but these have not been assessed in detail.

6.0 DATA GAPS AND RECOMMENDATIONS FOR FURTHER STUDY

6.1 SUPERSATURATION OF DISSOLVED GASES

Total dissolved gas (TDG) saturation levels in the Columbia River below the Hugh Keenleyside Dam periodically reach levels that would be lethal to fish remaining at shallow depths. Additional studies should be undertaken to determine the precise operating conditions that lead to the high TDG levels and the distributional effects (vertical and horizontal) that high TDG saturation levels have on sport fish. The studies also should be designed to determine the extent to which the fish populations in the lower Columbia River are being affected by "gas bubble disease." It also would be useful to know the extent to which fish avoid problems related to the high TDG saturation levels by remaining deep in the water column, or if they spend short periods of time in the shallows to feed but return to deep water before substantial problems develop. Since high TDG levels may occur in the reservoir during the drawdown period when operated under Regime 1, high mortalities may result if the fish do not avoid the shallow areas. If TDG levels are low for the period that the reservoir is full and then increase immediately after drawdown, the fish may not effectively avoid the high levels as they do under the existing river conditions where TDG levels may be high throughout most of the year.

6.2 IMPORTANCE OF *MYTIS RELICTA* IN THE STUDY AREA

Due to the rapid flushing rate and annual drawdown of the reservoir, *in situ* production of fish food organisms would be limited. As a consequence, the primary fish food source in the Murphy Creek reservoir would be zooplankton entering from Arrow Lakes, or from upstream impoundments on the Kootenay River. *Mytis relictus*, a large zooplankton, is presently one of the major food items for kokanee and other species of fish. A sampling program should be established to determine quantitatively the biomass of zooplankton (including mysids) entering the system throughout the year. Information relating to the present rate of exploitation of mysids by fish and other organisms within the study area would be useful in determining more closely the fisheries carrying capacity of the future reservoir. For example,

if mysids are being only lightly harvested within the proposed reservoir area, the reservoir may be able to support substantially more kokanee than the present river system. Alternatively, if the mysids are being heavily cropped within the first few kilometres of the Hugh Keenleyside Dam, then the carrying capacity of the reservoir for kokanee would approximate that of the present river system.

6.3 KOKANEE STOCKS

Indirect evidence obtained during the present study suggests that the kokanee that spawn in Norns Creek migrate into the area from downstream areas (i.e., Lake Roosevelt). Since kokanee die soon after spawning, they cannot be tagged in the spawning stream to determine movement patterns as can some of the repeat spawning species (e.g., rainbow trout). To determine with greater certainty the origin of these specific stocks of kokanee, a short tagging program should be undertaken in early August of 1981, preferably in Washington State where the Columbia River enters Lake Roosevelt.^a It is likely that the spawning escapement in 1981 will be large, corresponding to a large number of fish that spawned in Norns Creek in 1977 (estimated to have been 5000 fish). A study using conventional Floy anchor tags and possibly a limited number of radio tags could reduce the uncertainty surrounding the origin of the kokanee spawning in Norns Creek. Also, since many of the kokanee that were tagged during the present study were only 2-year-olds, an examination should be made of the kokanee in Norns Creek in 1981 to determine if any previously tagged fish are present.

6.4 SPORT FISH MOVEMENTS PAST THE DAMSITE

As mentioned above for kokanee, the extent of movement of other sport fish species past the damsite should be determined in order to better assess the potential impacts of the development, and to determine the

^aA study of the kokanee stocks that spawn in Norns Creek was initiated in mid-August 1981, and is presented as an addendum at the end of this volume.

benefits of incorporation of fish passage facilities in the dam. It is felt that this study could best be accomplished through an intensive sport fish tagging program above and below the damsite, using both conventional anchor tags and radio tags.

6.5 EXTENT OF RECRUITMENT FROM ARROW LAKES RESERVOIR

A study should be conducted to determine timing and extent of recruitment of fish from the Arrow Lakes Reservoir into the Murphy Creek Project study area. This investigation also should address the mode of transport (i.e., spillway, low level ports, boat lock) of fish past the Hugh Keenleyside Dam, and survival of the entrained fish. It is likely that this study could best be accomplished using hydroacoustic techniques.

6.6 POST IMPOUNDMENT STUDY

If the Murphy Creek Project proceeds and a reservoir is created, biological monitoring should be conducted to determine the diversity and abundance of fish stocks that develop, and to monitor the physical and chemical characteristics in the reservoir. These data can then be compared to the predictions made relating to the impacts of the project. Any discrepancies between predicted and actual post impoundment conditions can then be analyzed to improve the predictive capability for any future hydroelectric developments.

It also is recommended that the physical, chemical, and biological conditions that develop in the reservoir be studied before final plans are completed in regard to fisheries enhancement in the reservoir. This will facilitate the implementation of the most cost-effective fisheries enhancement program.

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251

8.0. PLATES



Plate 1. Columbia River at Km 27 looking downstream, 1 May 1980.

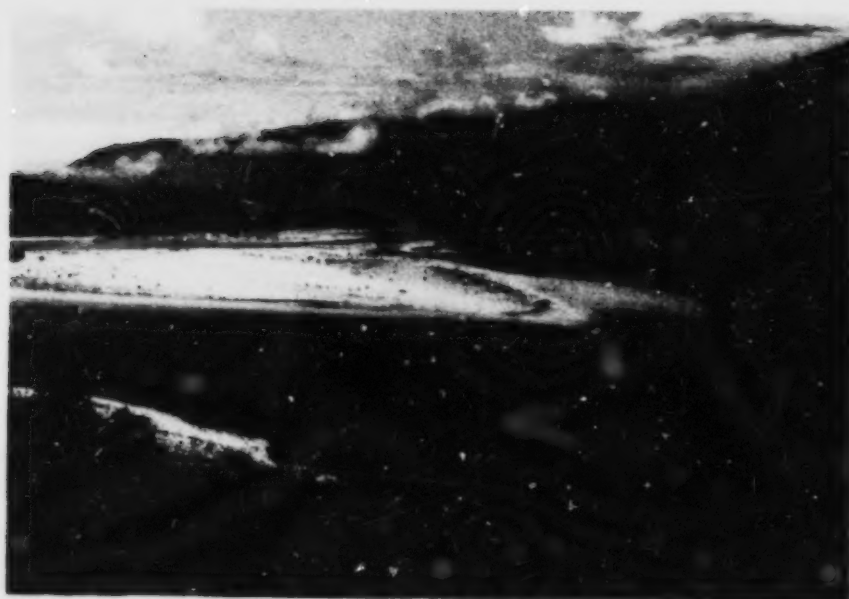


Plate 2. Columbia River at Km 31 looking upstream, 31 August 1980. Note large cobble and gravel bars.

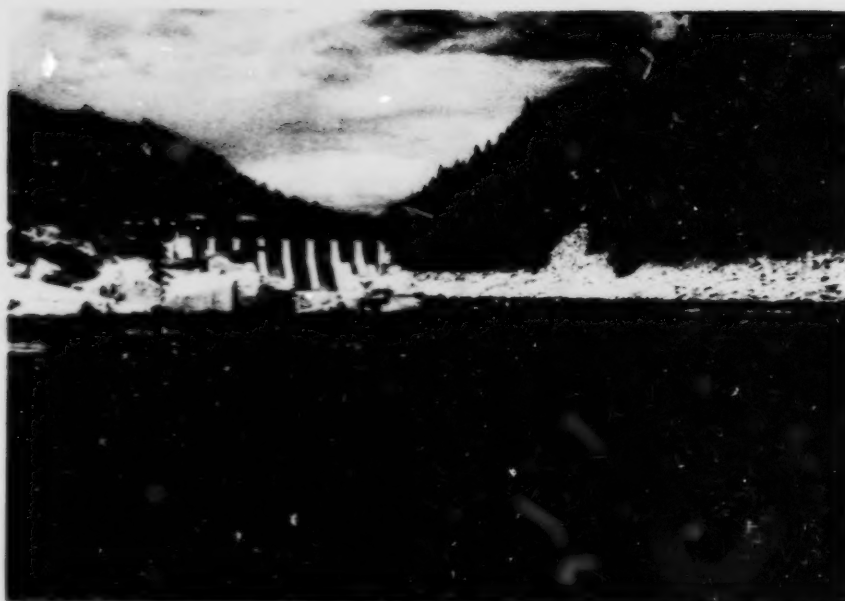
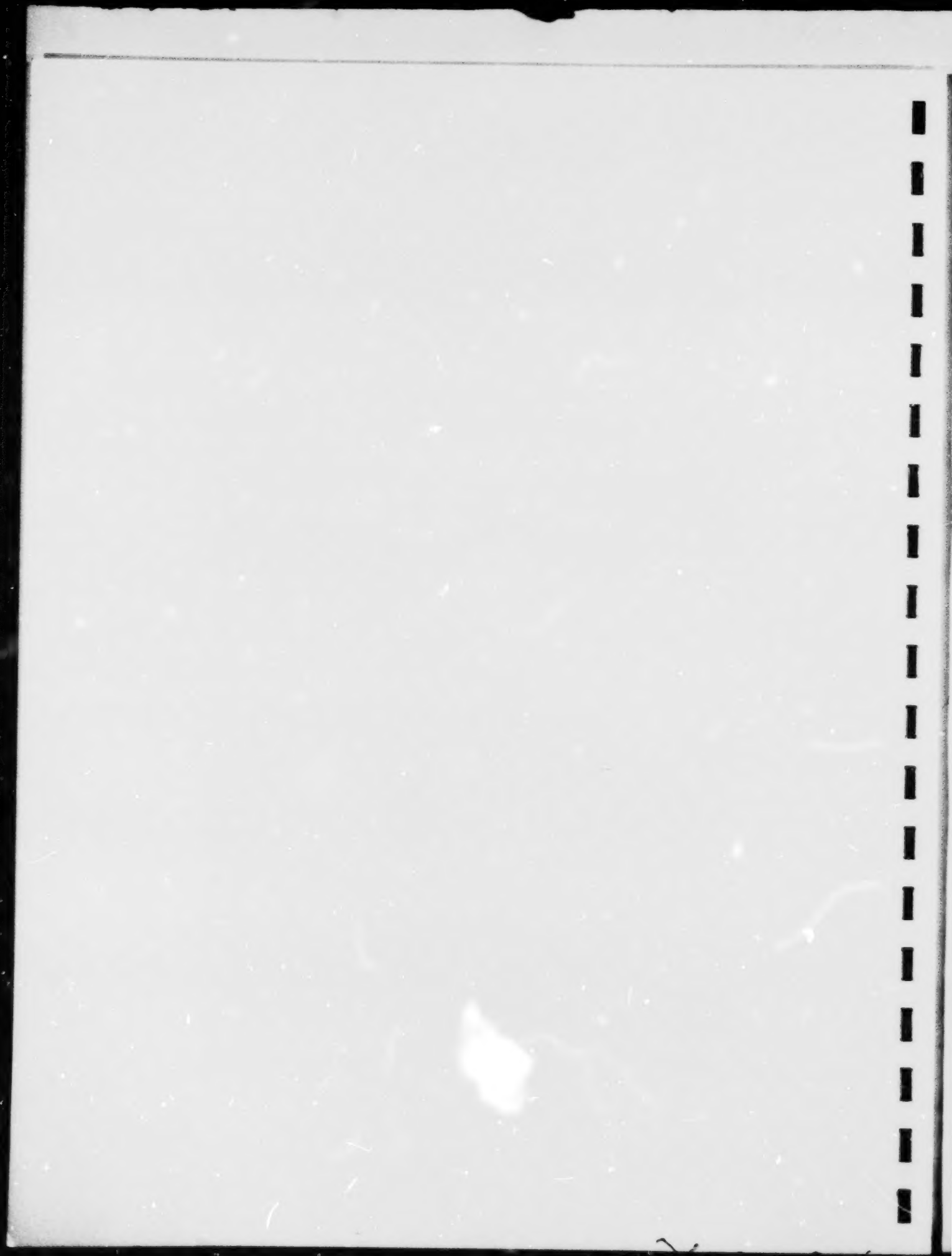


Plate 3. Kootenay River looking upstream toward the Brilliant Dam, 13 July 1980.



Plate 4. Norns (Pass) Creek at Km 1.4 looking downstream, 5 September 1980.



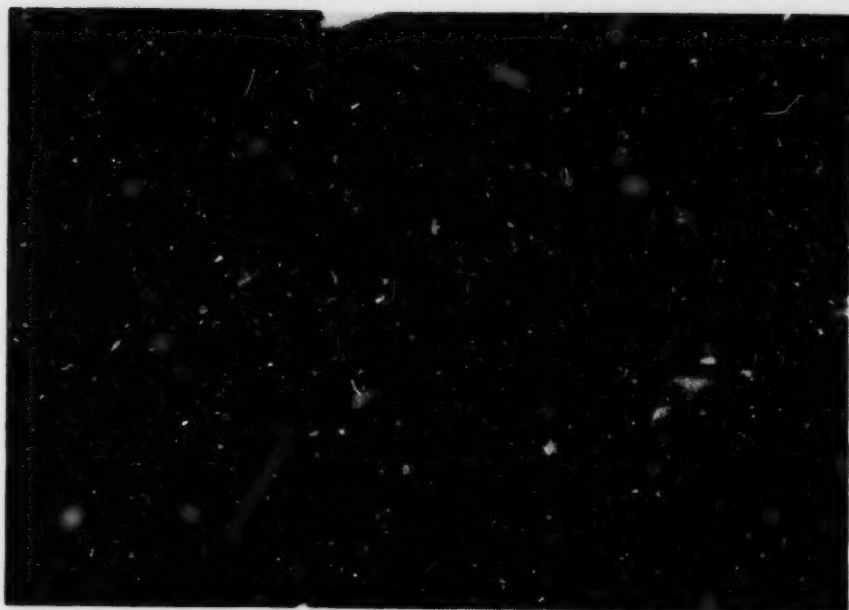


Plate 5. Champion Creek at Km 1.3 looking downstream, 6 September 1980. This tributary is used by rainbow trout for spawning and rearing.



Plate 6. Blueberry Creek viewed upstream from Km 1.4, 9 September 1980. Note the large exposed boulders. This section provides rearing habitat for rainbow trout.



Plate 7. China Creek at Km 0.9 looking downstream, 10 September 1980. Note the dense riparian vegetation and coarse substrate.



Plate 8. Murphy Creek viewed downstream from Km 1.5, 8 September 1980. Note the dense riparian vegetation and coarse substrate.



Plate 9. Kokanee spawning in Norns (Pass) Creek, 2 September 1980. Note the uniform size of the substrate.

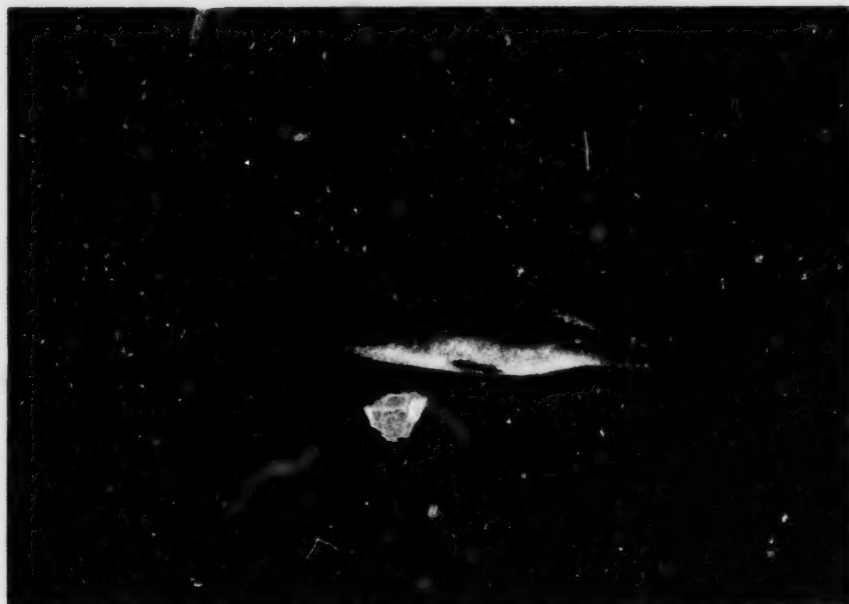


Plate 10. Rainbow trout from the Columbia River (Km 13) below Trail, 31 August 1980.

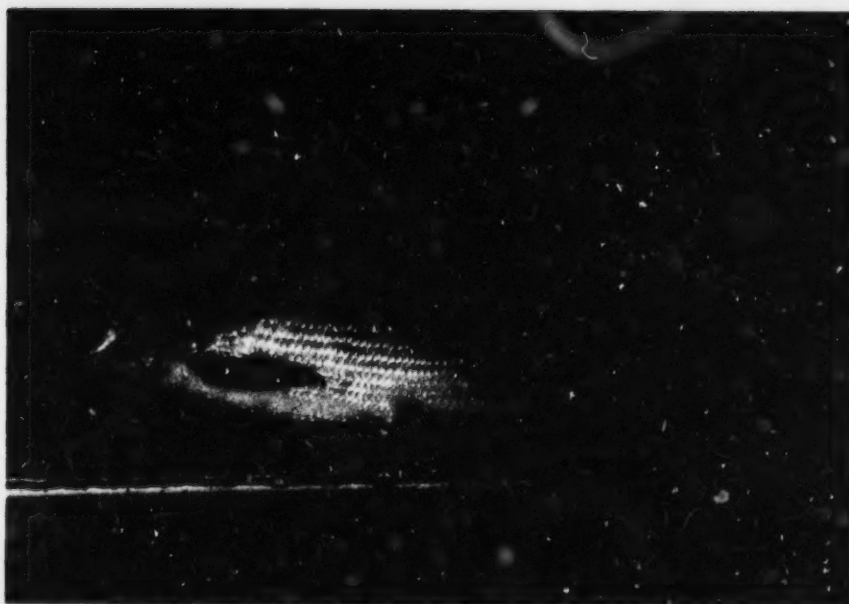


Plate 11. Lake whitefish captured just downstream of the Hugh Keenleyside Dam, 3 May 1980.

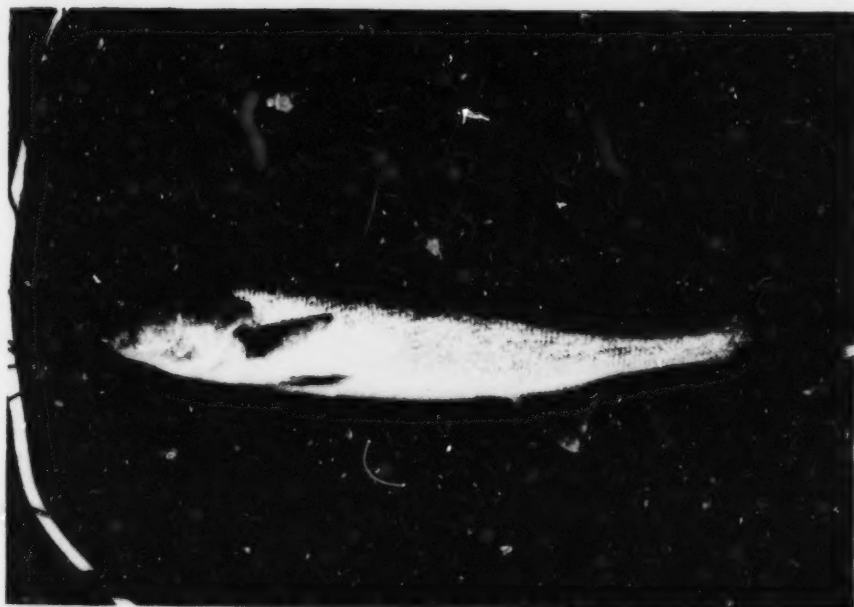


Plate 12. Walleye captured from the Columbia River at Km 48 near Castlegar, 28 August 1980. This sport fish species has recently expanded its range upstream from Lake Roosevelt into the study area.

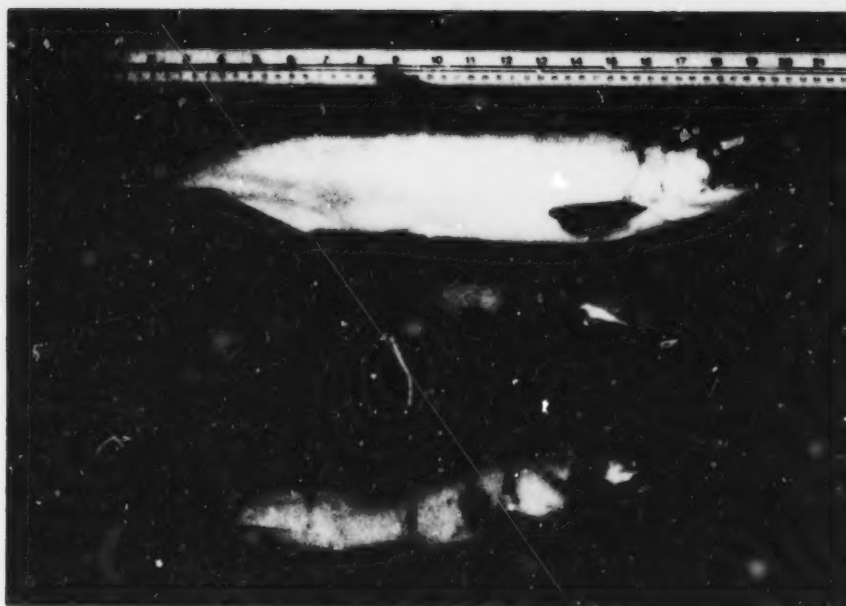


Plate 13. Three kokanee taken in a gill net set just below the CPR bridge on the Columbia River at Castlegar, 31 August 1980. Note the difference in colouration between the specimens. The top fish was an immature female.



Plate 14. Rainbow trout captured in Norns Creek, 19 April 1981. Note spawning colouration.

Appendix A

SUMMARY OF ELECTROFISHING CATCH
COLUMBIA RIVER DRAINAGE, 1980 AND 1981

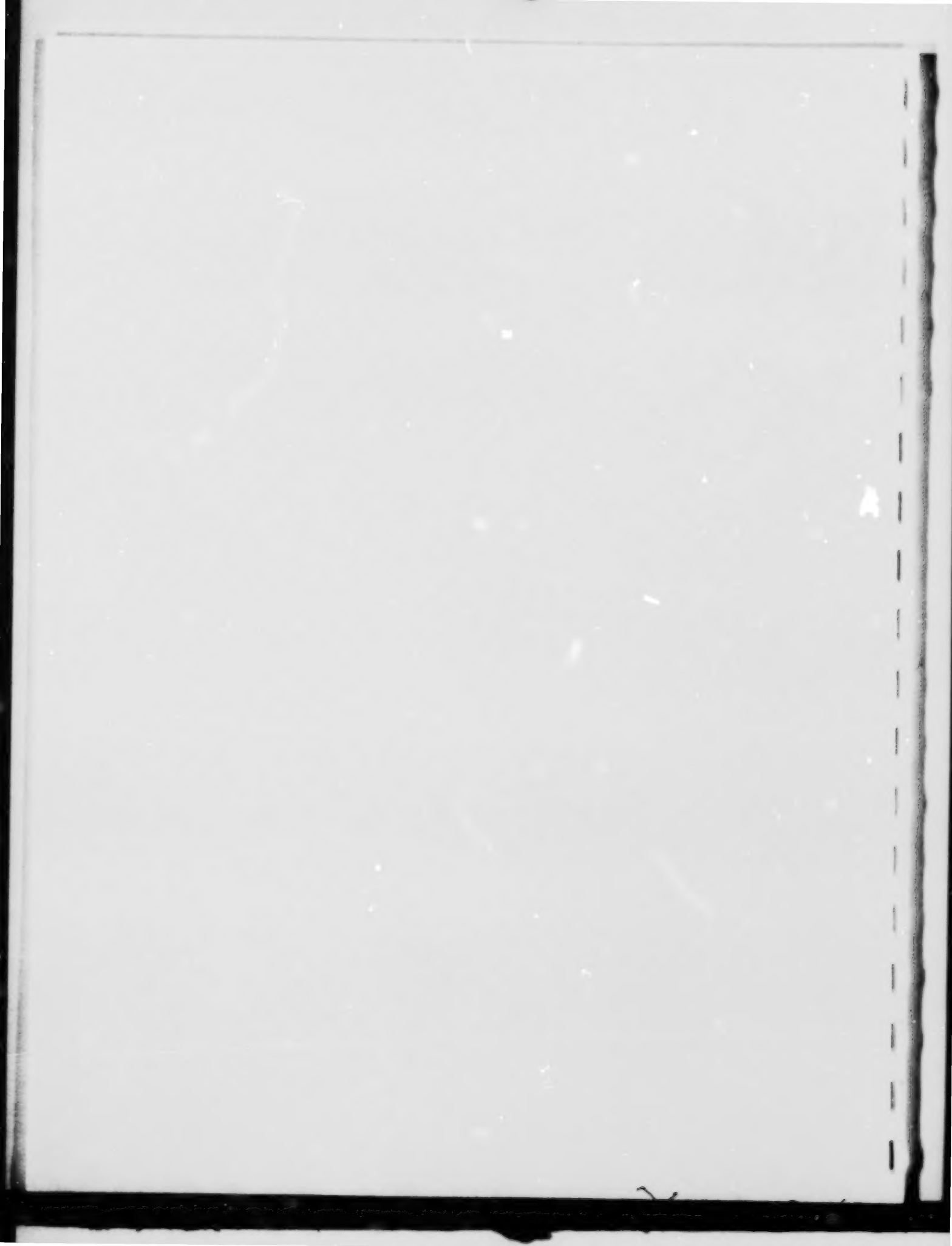


Table 4.1. Electrofishing catch and CUE (No. fish/km) for sample sections in the Columbia River, 29 April to 7 May 1980.

Section (km)	Date	Distance (km)	Duration (s)	Period ^b	Number ^a															Total		
					WU	K	RT	BT	DB	MD	LWS	LSS	BLS	NSP	LING	SCULPIN ^c	PA	RSS	CARP	Fish	CUE	
ES-8 (22.3-23.0)	29 April	0.5	372	D						5				2						7	14.0	
	4 May	1.3	763	D								12								12	9.2	
	4 May	0.6	611	D				1		2		2								5	8.2	
ES-9 (29.0-32.3)	4 May	1.5	770	D						1		1								2	1.3	
ES-16 (45.5-49.2)	30 April	1.0	625	D			2			9	11	1		1						14	14.0	
	30 April	2.3	334	D			1				11									4	13.3	
ES-17 (43.9-46.1)	30 April	0.5	606	D			1			2										3	6.0	
	30 April	0.6	299	D							11									1	1.7	
ES-18 (51.7-49.8)	3 May	0.5	1473	N		16	6			4				1						27	54.0	
ES-19 (53.1-51.7)	30 April	1.0	671	D																3	0.0	
	2 May	0.5	208	N		10	7			9	11	2								28	56.0	
	3 May	0.7	747	N		28	2		1	3	22									36	51.4	
	3 May	0.7	1623	N		24	3			6	15	2		1						39	55.7	
ES-20 (54.1-53.1)	30 April	0.3	167	D																0	0.0	
	3 May	0.6	991	N		12	3			2	22	1			5					26	43.3	
ES-21 (55.2-54.1)	3 May	0.4	501	N		2	3			5	11									11	27.5	
ES-22 (55.4-55.2)	30 April	2.3	216	N																0	0.0	
	3 May	0.3	362	N		2			2			1		2		2				9	10.2	
ES-27 (57.5-49.8)	30 April	2.5	217	D																0	0.0	
ES-28 (51.9-50.6)	30 April	0.3	192	D						2								5		7	21.2	
	7 May	1.0	957	N		1				9		3		1					4	17	17.0	
ES-29 (56.2-55.6)	30 April	1.4	360	D						1										1	2.5	
	7 May	0.4	71	N							11								107	108	270.0	
Along log house at Camden	7 May	0.4	216	N																100	100	250.0
Totals		18.6				2	15	28		3	56	17	25	3	8	6	2	5	211	457		
CUE (No. fish/km)						6.5	2.0			0.2	3.8	2.2	1.7	0	0.5	0.4	0.1	2.1	14.4		32.3	

^aTotal fish encountered (captured and reserved).^bD = day; N = night.^cObserved only, not identified to species.

Table A.2. Electrofishing catch and CUE (No. fish/km) for sample sections in the Columbia and Kootenay rivers, 11-16 July 1980.

Section (km)	Date	Distance (km)	Duration (s)	Period ^b	Number ^a																Total Fish	CUE
					YW	K	RT	BT	DV	HW	Suckers ^c	LWS	LSS	BLS	NSF	LIMG	SCULPIN ^c	PM	RSS			
MAINSTEM COLUMBIA RIVER																						
ES-2 (10.5-9.5)	16 July	1.0	700	D						1			15								16	26.0
ES-6 (17.4-16.2)	16 July	2.0	735	D			4			3	9		6				5				27	13.5
ES-8 (16.2-13.8)	16 July	0.4	199	D									6								6	15.0
ES-7 (20.0-17.4)	16 July	2.0	936	D			5				5		1		1						12	6.0
ES-9 (22.3-20.0)	16 July	2.3	1554	D						3											3	2.7
ES-15 (42.5-40.2)	15 July	1.3	797	D						2	10		5								17	13.1
ES-16 (44.5-43.2)	15 July	1.3	1003	D		1	1			8	10		5	2							27	20.7
ES-17 (46.9-48.1)	15 July	0.9	318	D							1										1	2.7
ES-18 (51.7-49.8)	12 July	1.9	777	N		52				272	3					3			500	930	416.8	
	14 July	1.9	2079	N		57	10			102	55		2			4	200		1000	3426	2807.2	
ES-19 (53.1-51.7)	12 July	1.4	1130	N		248	2								1							
	14 July	1.4	1201	N		79	15			76	37		8		2	3	40		1000	1272	908.6	
ES-20 (54.1-53.1)	12 July	1.0	757	N		43				55		5				3			900	1041	750.7	
	14 July	1.0	317	N		29				304		21			2	5	50		1000	1129	2228.0	
ES-21 (55.2-54.1)	12 July	1.1	794	N		16	10			51		1	2		2				2000	7084	1440.0	
	14 July	1.7	763	N		4	1			39		1	1		9	9	1		2001	2065	1214.7	
ES-22 (55.3-55.2)	12 July	0.7	123	N																		
	12 July	1.1	918	N																		
	14 July	0.8	793	N							2										1	1.4
ES-24 (47.3-46.5)	15 July	1.0	325	D						31					3				75	93	75.4	
ES-25 (48.3-47.5)	13 July	0.8	615	N																		
	15 July	0.8	348	D						49	50		6	4	7						0	
ES-26 (49.8-49.2)	11 July	0.5	772	N						33	60	13	5			1			751	751	1614	1028.0
	13 July	0.6	755	N		7	1			154	400	3	3			1	1	20	1	2000	2591	4718.3
ES-27 (50.6-49.8)	11 July	0.8	1001	N		3				27	20	3	3		2	1	3		501	1000	1561	1951.7
	13 July	0.8	993	N		8				400	403	5	13		1		20		1	300	1150	4437.5
ES-28 (51.5-50.6)	11 July	1.3	561	N		8				5	34	6			2	1			355	505	917	705.4
	13 July	1.3	404	N		3				52	4	2	7			3	15		1	500	589	453.2
ES-29 (54.2-55.6)	11 July	0.6	433	N																		
	13 July	0.6	400	N																		
Totals		34.2				568	51		2	1649	1108	49	90	6	36	34	354	1629	23124	28740		
CUE (No./km)						16.6	2.3		0.2	48.9	22.4	2.0	2.6	0.2	1.1	1.0	20.4	47.6	976.1	28740		840.4
KOOTENAY RIVER																						
ES-K1 & K3	15 July	1.7	1000	D						3			14	1							18	10.6
ES-K2	15 July	0.4	775	D																		
Totals		2.1									31										49	232.5
CUE (No./km)											14.8										67	32.4

^aTotal fish encountered (captured and observed).^bD = day N = night.^cObserved, not identified to species.

Table A.3. Electrofishing catch and CUE (No. fish/km) for sample sections in the Columbia River, 26 August to 7 September 1980.

Section (Km)	Date	Distance (km)	Time (s)	Number ^a																	Total Fish	CUE
				VV	K	RT	BT	DV	MV	Suckers ^b	LWS	LSS	BLS	WSF	LING	SCULPIN ^b	PH	RSS	CARP			
ES-1 (9.5-8.9)	31 Aug. ^c	0.6	1014			2			8	98		22								130	226.7	
ES-2 (10.5-9.5)	31 Aug. ^c	1.0	562			1			4	45		16			23					89	89.0	
ES-4 (13.8-12.9)	31 Aug. ^c	0.9	1586			3			6	34		8			1					52	57.8	
ES-5 (16.2-13.8)	31 Aug. ^c	1.4	310						16	15		5		1						37	26.4	
ES-6 (17.4-16.2)	31 Aug. ^c	1.2	436				1		9	20		13		1						44	36.7	
ES-7 (20.0-17.4)	31 Aug. ^c	1.6	380						23	15		2								40	25.0	
ES-8 (22.3-20.0)	1 Sept. ^c	2.3	1247			1			36	11		6			20					74	32.2	
ES-10 (31.5-29.0)	1 Sept. ^c 7 Sept. ^c	1.5 1.5	800 932			1			99 7	12 30		3 5			12					127 42	84.7 28.0	
ES-12 (37.2-36.2)	7 Sept. ^c	1.0	621						2	18		2			15					37	37.0	
ES-13 (39.0-37.2)	1 Sept. ^c	1.8	1369						4	23		9			80			50		166	92.2	
ES-14 (40.2-39.5)	7 Sept. ^c	1.3	777						4	24		4					1			33	25.3	
ES-16 (45.5-43.2)	7 Sept. ^c	2.0	778	1	1				44	35		24	4							109	54.5	
ES-18 (51.7-49.8)	27 Aug. ^d 29 Aug. ^d	1.9 1.9	2056 2372	1 3	7 3	1 1			2 413	572 128	5 6	1 5		1 4	2 3	230 86	2 2	2500 1500		3324 2451	1749.5 1290.0	
ES-19 (53.1-51.7)	27 Aug. ^d 29 Aug. ^d	1.4 1.4	1091 775	1 1	3 1	1 1			47 153	66 503	1 2	2 1			1 2			3000 2500		3122 3202	2230.0 2287.2	
ES-20 (54.1-53.1)	27 Aug. ^d 29 Aug. ^d	1.0 1.0	1121 1062		6 4				50 127	2 504		2 1		1 4	7 6	15 50			1 3500		81 4199	81.0 4199.0
ES-21 (55.2-54.1)	27 Aug. ^d 29 Aug. ^d	1.1 1.1	536 661		3 1				2 41	17 18	1 1	1 2			19 15			24 1200		1 1301	70.9 1182.7	
ES-22 (55.9-55.2)	27 Aug. ^d 29 Aug. ^d	0.7 0.7	575 558		1				4 16					1 2	1 7					7 51	20.0 72.9	
ES-24 (47.5-46.5)	28 Aug. ^d	1.0	422	1					17	10		2						25		30	30.0	
ES-25 (48.3-47.5)	26 Aug. ^d 28 Aug. ^d	0.8 0.8	552 436	1	4				6 5	28		1 2		2 1				8		50 8	62.5 10.0	
ES-26 (49.8-49.2)	26 Aug. ^d 28 Aug. ^d	0.6 0.6	759 784								170 1005	1 3	3 7		4 1	10 50		2503 6000		2692 7420	4496.7 12366.7	
ES-27 (50.6-49.8)	26 Aug. ^d 28 Aug. ^d	0.8 0.8	1050 1057		2				51 500	314 309	2 2	1 2		1		50 40		3500 5000		3921 5853	4901.2 7316.2	
ES-28 (51.9-50.6)	26 Aug. ^d 28 Aug. ^d	1.3 1.3	815 756		2 2			1	226 202	499 4	2 3	4 7	1 7	2 7	1 50	50 50	1 1	5008 5000		5797 5269	4459.2 4053.2	
ES-29 (56.2-55.6)	26 Aug. ^d 28 Aug. ^d	0.6 0.6	396 275			1				7	3	1						246 100		247 112	412.7 186.7	
ES-30 (56.2)	26 Aug. ^d 28 Aug. ^d	0.3 0.3	206 558	1 3					31	15	1			2				150 500		150 554	500.0 1846.7	
Totals		40.1		6	44	11	1	4	2514	4548	32	161	5	25	83	837	13	42614	1	50899		
CUE (No./km)				0.2	1.2	0.3	0.02	0.2	62.7	123.4	0.9	4.0	0.2	0.6	2.2	20.9	0.3	1062.7	0.02	1269.3		

^aTotal fish encountered (captured and observed).^bObserved only, not identified to species.^cDay.^dNight.

Table A.4 Electrofishing catch and CUE (No. fish/km) for sample sections in the mainstem Columbia River, January 1981.

Section (km)	Date	Distance Time (km)	(s)	Period ^b	Number ^a										Total Fish	CUE (No./km)						
					YV	K	RT	BT	DV	HW	Suckers ^c	INS	LSS	BLS			NSF	LING	Sculpin	PH	RSS	
ES-17 (48.9-48.1)	29 Jan.	0.8	735	N						2										2	2.5	
ES-18 (51.7-49.8)	29 Jan.	1.9	1296	N	1				1	6							2			150	160	84.2
ES-19 (53.1-51.7)	29 Jan.	1.4	821	N					1	12	7						5				25	17.9
ES-20 (54.1-53.1)	29 Jan.	1.0	957	N								3			1					6	10	10.0
ES-21 (55.2-54.1)	29 Jan.	1.1	582	N						1	20			1						320	342	310.9
ES-22 (55.9-55.2)	29 Jan.	0.7	507	N					2	2											4	5.7
ES-24625 (48.3-46.5)	29 Jan.	1.8	325	N						43	20		2								65	36.1
Totals		8.7			1				4	66	47	3	3		7	7				476	608	
CUE (No./km)					0.1				0.5	7.6	5.4	0.1	0.1		0.1	0.8				54.7	69.9	

^a Includes number actually captured and number observed.^b D = day, N = night.^c Observed only, not identified to species.

Table A.5. Electrofishing catch and CUE (No. fish/km) for sample sections in the mainstem Columbia River, May 1981.

Section (km)	Date	Distance (km)	Time (%)	Number ^a										Total Fish	CUE
				RT	K	MW ^b	Suckers ^{b,c}	Suckers ^{d,e}	NSF	RSS	Sculpin ^c	LING	CARP		
ES-17 (48.9-48.1)	5 May ^e	0.8	932	1		40	500	10	30	2000				2581	3226.2
ES-18 (51.7-49.8)	5 May ^e	0.9	934	1		30	200	10	10	1500	100			1851	2056.7
ES-19 (53.1-51.7)	5 May ^e	1.4	694						1	500	75			576	411.4
ES-20 (54.1-53.1)	5 May ^e	1.0	674				5			25	6			36	36.0
ES-21 (55.2-54.1)	5 May ^e	1.1	640			20		10		75				105	95.4
ES-22 (55.9-55.2)	5 May ^e	0.7	595	1		12			4	150				167	238.6
ES-26 (49.8-49.2)	6 May ^e	0.6	740	1		105	200	6	10	3000	100			3422	5703.3
ES-27 (50.6-49.8)	6 May ^e	0.8	596			300	300	15	15	2500	400	2	1	3533	4416.2
ES-28 (51.9-50.6)	6 May ^e	1.3	673		2	200	100	10	50	4000	500			4862	3740.0
ES-29 (56.2-55.6)	6 May ^e	0.6	232				100			1500				1600	2666.7
ES-30 (56.2)	6 May ^e	0.3	475				200	1		5000	50			5251	17503.3
Totals CUE (No./km)		9.5	7185	4 0.4	2 0.2	707 74.4	1605 168.9	62 6.5	170 12.6	20250 2131.6	1231 129.6	2 0.2	1 0.1	23984	2524.6

^aTotal fish encountered (captured and observed).^bJuveniles only.^cObserved only, not identified to species.^dAdults only.^eNight.

Table A.6. Electrofishing catch and CUE (No. fish/100 m²) for all tributary sample sections, Columbia River, 12-17 July 1980.

Location (km)	Date	Time (s)	Area Sampled (m ²)	Numbers and CUE						Total CUE
				RT ^a	Sculpins	Suckers ^a	Lhu	RSS	Unidentified Fry	
<u>Norns Cr.</u>										
(0-0.2)	12 July	228	800		43 5.4		2 0.2		8 1.0	53 6.6
(0.2-0.5)	12 July	164	400		12 3.0		1 0.3		12 3.0	25 6.3
(0.7-0.9)	14 July	112	200	38 19.0	35 17.5				67 33.5	140 70.0
(1.0-1.2)	14 July	571	680		43 6.3			2 0.3	45 6.6	90 13.2
(1.3-1.5)	14 July	139	240		26 10.8	3 1.3	1 0.4		35 14.6	65 27.2
Total		1214	2320	38 1.6	159 6.9	3 0.2	4 0.2	2 0.2	167 7.2	373 16.1
<u>Blueberry Cr.</u>										
(1.2-1.25)	17 July	117	414	66 25.9						66 15.9
<u>China Cr.</u>										
(1.1-1.15)	17 July	164	152						130 85.5	130 85.5
(1.25-1.3)	17 July	242	330	2 0.6					2 0.6	2 0.6
Total		406	482	2 0.4					130 27.0	132 27.4
<u>Champion Cr.</u>										
(0.1-0.2)	17 July	99	216	154 71.3	19 8.8					173 80.2
(0.4-0.5)	17 July	236	216	36 19.9	1 0.5					87 40.3
(0.8-0.9)	17 July	81	216	127 58.8						127 58.8
Total		416	648	367 56.6	20 3.2					387 59.7
<u>Murphy Cr.</u>										
(0.58-0.62)	17 July	298	648	17 2.6						17 2.6

^a includes young-of-the-year.

Table A.7. Electrofishing catch and CUE (No. fish/100 m²) for all tributary sample sections, Columbia River, 11-12 Sept. 1980.

Location (km)	Date	Time (s)	Area Sampled (m ²)	Number and CUE			Total CUE
				RT ^a	Sculpins	LND	
<u>Norns Cr.</u>							
(2.3)	11 Sept.	92	24		1 4.2		1 4.2
(2.37)	11 Sept.	150	60		1 1.7		1 1.7
(2.4)	11 Sept.	53	40				0
(2.46)	11 Sept.	169	300		4 1.3		4 1.3
(2.75)	11 Sept.	145	100		4 4.0		4 4.0
(2.9)	11 Sept.	275	60	41 68.3	20 33.3		61 101.7
(3.2)	11 Sept.	320	60	1 1.7	15 25.0	7 11.7	23 38.3
(3.3)	11 Sept.	155	40	2 5.0	5 12.5		7 17.5
(3.45)	11 Sept.	100	40	2 5.0	4 10.0		6 15.0
Total		1457	724	46 6.4	54 7.5	7 1.0	107 14.8
<u>Blueberry Cr.</u>							
(0.85-0.95)	12 Sept.	342	138	167 121.0	6 4.3	1 0.7	174 126.1
(1.2-1.25)	12 Sept.	84	102	34 33.3	3 2.9		37 36.3
Total		426	240	201 83.8	9 3.8	1 0.4	211 87.9
<u>China Cr.</u>							
(1.10-1.15)	12 Sept.	271	152	100 65.8			100 65.8
(1.25-1.3)	12 Sept.	301	137.5	42 30.5			42 30.5
Total		572	289.5	142 49.1			142 49.1
<u>Champion Cr.</u>							
(1.4)	12 Sept.	90	54	219 405.6			219 405.6
<u>Murphy Cr.</u>							
(0.5-0.55)	12 Sept.	331	122.5	79 64.5			79 64.5
(0.7-0.75)	12 Sept.	225	202.5	55 27.2			55 27.2
Total		556	325	134 41.3			134 41.3

^a Includes young-of-the-year.

Table A.8. Electrofishing catch and CUE (No. fish/100 m²) for all tributary sample sections, Columbia River, 1-6 Feb. 1981.

Location (km)	Date	Time (s)	Area Sampled (m ²)	Number and CUE					Total CUE
				RT ^a	Sculpins	Suckers	LWD	CT	
<u>Norns Cr.</u>									
(0.7-0.8)	3 Feb.	299	400	4	3				7
				2.0	0.8				2.8
(1.0-1.1)	3 Feb.	203	480		2				2
					0.4				0.4
(1.1-1.2)	3 Feb.	104	360	1					1
				0.3					0.3
(1.3-1.4)	3 Feb.	56	180						0
(1.4-1.5)	3 Feb.	180	180		5				5
					2.0				2.0
Total		902	2000	5	10				15
				0.3	0.5				0.8
<u>Blueberry Cr.</u>									
(0.85-0.90)	5 Feb.	277	680	1	1				2
				0.2	0.2				0.3
(1.2-1.25)	5 Feb.	204	552	3	2				5
				0.5	0.4				0.9
Total		481	1232	4	3				7
				0.3	0.2				0.6
<u>China Cr.</u>									
(1.1-1.15)	6 Feb.	115	228	6					6
				2.6					2.6
(1.25-1.3)	6 Feb.	147	330	5				1	6
				1.5				0.3	2.8
Total		262	558	11				1	12
				2.0				0.2	2.2
<u>Murphy Cr.</u>									
(0.7-0.75)	6 Feb.	293	648	11					11
				2.7					2.7
<u>Champion Cr.</u>									
(0.1)	1 Feb.	123	360						0
(0.2)	1 Feb.	99	360						0
(0.4)	1 Feb.	115	360	2					2
				0.6					0.6
(0.8-0.85)	1 Feb.	106	360	3					3
				0.8					0.8
(1.2-1.25)	1 Feb.	93	288						0
(1.6-1.65)	1 Feb.	193	396	4					4
				2.0					2.0
Total		729	2124	9					9
				0.4					0.4

^a Includes young-of-the-year.

Table A.9. Electrofishing catch and CUE (No. fish/100 m²) for all tributary sample sections, 17-19 April 1981.

Location (Km)	Date	Time (s)	Area Sampled (m ²)	Numbers and CUE					Total CUE
				RT ^a	RT ^b	RT ^c	MW ^d	Sculpins	
<u>Norns Cr.</u>									
(0.15-1.0)	18 April	829	700		24	45	10	38	117
					3.4	6.4	1.4	5.4	16.7
(1.0-2.05)	18 April	562	160		22			50	72
					13.7			31.2	45.0
Total		1391	860		46	45	10	88	189
					5.3	5.2	1.2	55.0	22.0
<u>Blueberry Cr.</u>									
(0.85-0.95)	19 April	367	70			33			33
						47.1			47.1
<u>China Cr.</u>									
(0.01-0.1)	19 April	294	80			13			13
						16.2			16.2
(1.1-1.15)	19 April	620	70	1		24			25
				1.4		34.3			35.7
Total		914	150	1		37			38
				0.7		24.7			25.3
<u>Champion Cr.</u>									
(0.1-0.2)	17 April	180	120						0
(0.2-0.3)	17 April	113	120						0
(0.4-0.5)	17 April	91	80			1			1
						1.2			1.2
(0.6-0.7)	17 April	272	170			15			15
						8.8			8.8
(0.8-0.9)	17 April	204	90	1		5			6
				1.1		5.5			6.7
(0.9-1.0)	17 April	125	150			4			4
						2.7			2.7
Total		985	730	1		25			26
				0.1		3.4			3.6
<u>Murphy Cr.</u>									
(0.04-0.06)	19 April	450	70			25			25
						35.7			35.7
(0.58-0.62)	19 April	356	95			20			20
						21.1			21.1
Total		806	165			45			45
						27.3			27.3

^aStream resident adult rainbow trout.^bRiver resident adult rainbow trout.^cJuveniles only.^dYoung-of-the-year only.



Appendix B

SUMMARY OF GILLNET CATCH AND CUE, COLUMBIA
RIVER, 1980 AND 1981

Table B.1. Gillnet catch and CUE (No. fish/100 m²/24 h), Columbia River, 1-11 May 1980.

Station (km)	Date	Net Area ^a (m ²)	Duration of Set (h)	Number and CUE										Total CUE	
				K	AT	OV	HW	LW	LWS	LSS	BLS	LING	NSF		PN
GN-3 (47.5)	5 May	108	2.0		2		1	1	0	10			5		27
					22.0		11.0	11.0	88.1	110.1			55.0		297.2
	6 May	108	2.0		2		1	1	3	1			2	6	15
					22.0		11.0	11.0	11.0	11.0			22.0	66.0	165.1
GN-5 (56.1)	8 May	108	3.0												0
	11 May	108	9.7				1	1	6	14			2	1	24
							2.3	13.7	11.9				4.6	2.1	54.6
GN-6 (55.9)	2 May	108	18.5						1				2		3
									1.2				2.4		1.6
	3 May	108	8.2		5	1	1	1	1				2	21	33
					11.3	2.7	2.7	2.7	2.7				5.3	56.0	88.1
	11 May	108	4.5						1	5			4	10	10
GN-6 (55.9)									4.9	24.5			19.6		48.9
	11 May	108	4.3		1	4				1			5	11	11
					5.1	20.8				5.1			25.4		55.9
GN-6 (55.9)	1 May	108	24.7		2		1								3
					1.8		0.9								2.7
Totals CUE		108	76.9	6	11	1	5	2	20	31			22	28	126
				1.7	1.1	0.1	1.4	0.6	5.7	8.9			6.3	8.0	16.1

^aNets composed of 16 m² panels (15 m long x 2.4 m deep) of 3.8, 6.4, and 8.9 cm stretched mesh.

Table B.2. Gillnet catch and CUE (No. fish/100 m²/24 h), Columbia River, 11-16 July 1980.

Station (km)	Date	Duration of Set (h)	Net Area ^a (m ²)	Number and CUE										Total Fish	CUE
				K	RT	DV	FW	LV	INS	LSS	BLS	LING	NSF	PM	
GN-1 (18.2)	16 July	6.7	180												0
GN-2 (45.7)	14 July	20.5	180	1 0.7						2 1.1	2 1.1		2 1.1	2 1.1	9 5.0
GN-3 (47.5)	12 July	23.3	180												0
GN-5 (56.1)	11 July	4.7	180												0
Totals CUE		55.2	100	1 0.2						2 0.5	2 0.5		2 0.5	2 0.5	9 2.2

^aNets composed of 36 m² panels (15 m long x 2.4 m deep) of 3.8, 6.4, 8.9, 10.2, and 11.4 cm stretched mesh.

Table B.3. Gillnet catch and CUE (No. Fish/100 m² net/24 h), Columbia River, 31 Aug.-9 Sept. 1980.

Station (Km)	Date	Duration (h)	Net Area ^a (m ²)	Number and CUE										Total Fish	CUE
				K	RI	HW	LW	LNS	LSS	BLS	LING	NSF	PM		
GN-1 (18.2)	1 Sept.	11.2	144		4 6.0	1 1.5						1 1.9	1 1.5	7	10.6
GN-3 (47.5)	31 Aug.	16.25	144	2 2.1										2	2.1
	9 Sept.	13.3	144		2 2.5									2	2.5
GN-5 (56.1)	9 Sept.	12.5	144		1 1.1							2 2.7		3	4.0
Total CUE		53.25	144	2 0.6	7 2.2	1 0.3						3 0.9	1 0.3	14	4.4

^aNets composed of 36 m² panels (15 m long x 2.4 m deep) of 3.8, 6.4, 8.9 and 10.2 cm stretched mesh.

Table B.4. Gillnet catch and CUE (No. fish/100 m²/24 h), Columbia River, 30 Jan.-5 Feb. 1981.

Station Location (Km)	In Column	Date	Duration (h)	Net Area ^a (m ²)	Number and CUE											Total Fish CUE
					K	RT	DV	MW	LM	LNS	LSS	BLS	LING	MSF	PH	
GN-1 (18.2)	Surface	5 Feb.	26.1	180		1 0.5		2 1.0	1 0.5		1 0.5			1 0.5		6 3.0
GN-2 (45.7)	Bottom	5 Feb.	17.6	180			1 0.8	6 4.5	1 0.8					1 0.8		9 6.8
GN-4 (54.2)	Bottom	4 Feb.	18.6	180				5 1.6	2 1.4				1 0.7			8 5.7
GN-5 (56.1)	Surface	30 Jan.	17.0	180		1 0.8			2 1.6					1 0.8		4 3.1
	Surface	2 Feb.	71.2	180	1 0.2			1 0.2	2 0.4					1 0.2		5 0.9
	Bottom	3 Feb.	16.6	180	3 2.4	1 0.8			1 0.8					1 0.8		6 4.8
	Bottom	4 Feb.	24.3	180												0 0.0
Totals CUE			191.4	180	4 0.1	3 0.2	1 <0.1	14 1.0	9 0.6		1 <0.1		1 <0.1	5 0.3		38 2.6

^aNets composed of 36 m² panels (15 m long x 2.4 m deep) of 3.8, 6.4, 8.9 and 10.2 cm stretched mesh.

Appendix C

SEINE HAUL, FISH TRAP, SET LINE, AND FLOAT
SURVEY SUMMARY, COLUMBIA RIVER, 1980 AND 1981

Table C1. Beach seine catch and CUE (No. Fish/100 m²), Columbia River, 1980 and 1981.

Station (Km)	Date	Number of Hauls	Area (m ²)	Number and CUE								Total Fish	CUE
				RT	HW	Sucker ^a	LWS	LSS	Sculpin ^a	PM	ASS		
SPRING													
BS-1 (29.1)	6 May	3	220		9 4.1					1 0.5	1 0.5	11	5.0
BS-2 (32.3)	6 May	3	360		65 18.1							65	18.1
BS-3 (37.4)	6 May	3	300		36 12.0							36	12.0
BS-4 (41.7)	6 May	3	240	1 0.4	5 2.1			1 0.4				7	2.9
BS-5 (45.5)	6 May	3	360						1 0.3			1	0.3
BS-6 (51.5)	6 May	3	280		9 3.2				6 2.1		1 0.4	16	5.7
SUMMER													
BS-1 (29.1)	18 July	4	340	3 0.9		24 21.8						77	22.6
BS-2 (32.3)	18 July	3	260	1 0.4		5000 1923.1						5001	1923.5
BS-3 (37.4)	18 July	3	320		1 0.3	49 15.3						50	15.6
BS-4 (41.7)	18 July	3	220	1 0.5		54 24.5						55	25.0
BS-5 (45.5)	18 July	3	260			18 6.9			3 1.2		1 0.4	22	8.5
BS-6 (51.5)	18 July	3	300			30 10.0					1 0.3	31	10.3
Km 33.1	18 July	1	100	1 1.0		1 1.0						2	2.0
Km 35.9	18 July	1	125	8 6.4		23 18.4						31	24.8
FALL													
BS-1 (29.1)	7 Sept.	3	315	1 0.3								1	0.3
BS-2 (32.3)	7 Sept.	3	270			235 102.2				3 1.3	124 53.9	362	137.4
BS-3 (37.4)	7 Sept.	3	285			14 4.9					4 1.4	18	6.3
BS-4 (41.7)	7 Sept.	3	310			30 9.7			1 0.3		1 0.3	32	1.3
BS-5 (45.5)	7 Sept.	3	300			6 2.0			1 0.3		1 0.3	8	2.6
BS-6 (51.5)	7 Sept.	3	310			1 0.3			23 7.4			24	7.7
WINTER													
BS-1 (29.1)	30 Jan.	3	300										
BS-2 (32.3)	30 Jan.	3	240										
BS-3 (37.4)	30 Jan.	3	340										
BS-4 (41.7)	30 Jan.	3	340					1 0.3				1	0.3
BS-5 (45.5)	30 Jan.	3	360										
BS-6 (51.5)	30 Jan.	3	600										

^aNot identified to species.

Table C.2. Gee minnow trap and hoop trap catch and CUE (No. fish/trap/day), Columbia River, 1980.

Station	Date Set	Trap Type	Duration Set (days)	Catch	CUE
Km 24.0 ^a	29 April	Baited Gee minnow	11		
		Large baited minnow	11		
Km 22.0 ^a	29 April	Baited Gee minnow	9.78	1 RSS	0.1
		Baited Gee minnow	9.78		
		Hoop trap	9.0		

^a Right downstream bank.

^b Left downstream bank.

Table C.3. Fish trap catch in Norns Creek, spring 1981.

Location (Km)	Date Checked	Number of Rainbow Trout		
		Upstream	Downstream	Total
T1 (0.15)	15 April	10		10
	16 April	6		6
	17 April	6		6
	18 April	11		11
	19 April	9		9
	20 April	13		13
	21 April	9		9
	22 April	8		8
	23 April	2		2
	24-25 April	Trap Out		
	26 April		2	2
	27 April		1	1
	28 April	2		2
	29 April	2	5	7
	30 April	3	1	4
	1 May		1	1
	2-5 May	Trap Out		
	6 May	1		1
	7 May	1		1
	8 May	1		1
Totals -	15 April to 8 May	84	10	94

Table C.4. Fish trap catch in Champion Creek, spring 1981.

Location (Km)	Date Checked	Number of Rainbow Trout		
		Upstream	Downstream	Total
T2 (0.1)	17 April	0	-	
	18 April	0	-	
	19 April	0	-	
	20 April	0	-	
	21 April	0	-	
	22 April	1	-	1
	23 April	0	-	
	24 April	0	-	
	25-28 April	Trap Out		
	29 April	0	0	
	1 May	1	0	1
	2 May	1	0	1
	3 May	0	-	
	4 May	0	-	
	5 May	0	-	
	6 May	0	-	
	7 May	2	-	2
Totals - 17 April to 7 May		7		7

Table C.5. Set line catch and CUE (No. fish/day), Columbia River, 1980.

Location (Km)	Date Set	Set Duration (days)	Catch	CUE (No. fish/day)
SL-1 (56.1)	2 May	2.0	2 Ling	1.0
SL-2 (56.0)	2 May	4.2	1 Ling	0.2
SL-3 (55.0)	2 May	0.8		
SL-4 (54.2)	2 May	5.0	2 Ling 1 NSF	0.6
SL-5 (53.9)	2 May	2.0		
SL-6 (53.8)	2 May	2.0		
SL-7 (53.7)	2 May	2.0		
Total		18.0	6	0.3

Table C.6. Float survey summary, Columbia River and Kootenay River, 1980.

Location (Km)	Date	Surveyed Distance (km)	Approximate Number Observed				Total
			RT	MW	Sucker ^a	Sculpin	
Kootenay R. (2.0-0)	10 July	2.0		20	300	3	323
Kootenay R. (2.0-0)	3 Sept.	2.0	8	11	135		154
Columbia R. (42.6-41.0)	3 Sept.	1.6		150	200		350

^a Not identified to species.

Appendix D

SUMMARY OF FISH RECAPTURES,
COLUMBIA RIVER, 1980 AND 1981

Table D.1. Summary of fish recaptures, Columbia River, 1980 and 1981.

Species	Tag Number	Release Date	Recapture Date	Release Location (km)	Recapture Location (km)
K	F3a	11-13 July 1980	14 July 1980	-	51.0
K	F3a	11-13 July 1980	14 July 1980	-	54.0
K	01119	2 May 1980	b	53.1	55
K	01117	2 May 1980	b	51.7	b
K	01171	3 May 1980	b	51.7	b
RT	01186	3 May 1980	29 Aug. 1980	51.7	b
RT	01189	3 May 1980	b	49.8	b
RT	01129	3 May 1980	b	54.1	b
RT	01862	16 Apr. 1981	16 June 1981	Norns Creek	9 (near Beaver Creek)
RT	01866	17 Apr. 1981	10 July 1981	Norns Creek	22 (near Hanna Creek)
RT	01871	18 Apr. 1981	10 May 1981	Norns Creek	42 (below Castlegar Bridge)
RT	01896	19 Apr. 1981	17 May 1981	Norns Creek	27 (near Birchbank)
RT	01900	20 Apr. 1981	1 June 1981	Norns Creek	43 (Castlegar Bridge)
RT	01907	20 Apr. 1981	15 June 1981	Norns Creek	17 (below Trail Bridge)
RT	01914	21 Apr. 1981	4 July 1981	Norns Creek	25 (Birchbank Golf Course)
RT	01917	21 Apr. 1981	15 July 1981	Norns Creek	21
RT	01934	28 Apr. 1981	28 June 1981	Norns Creek	13 (Rock Island)
RT	01942	30 Apr. 1981	7 June 1981	Norns Creek	9 (Beaver Creek)
DV	01126	3 May 1980	14 July 1980	54.1	54.9
			1 March 1981	54.9	55.5
LING	01147	3 May 1980	14 July 1980	53.1	54.0
NSF	01103	29 Apr. 1980	31 July 1980	22.5	b

^a Adipose/anal fin clip.^b Angler recapture, specific data unknown.



Appendix E

DAILY TEMPERATURE AND STAFF
GAUGE RECORDINGS, APRIL-MAY 1981

Table E.1. Temperatures and staff gauge readings in Norrs Creek and the Columbia River, spring 1981.

Date	Weather Condition	Time	Norrs Creek		Staff Gauge Reading (cm)	Columbia River at Norrs Creek		
			Temperature			Time	Temperature	
			Air	Water			Air	Water
14 April	sunny, calm	1230	14.0	7.0		1800	14.0	5.5
	sunny, calm	1415	16.0	9.0				
	sunny, calm	1800	13.0	8.0	40			
15 April	sunny, calm	0730	3.5	4.0	40			
	sunny, calm	1930	12.0	7.5	40	1920	12.5	6.0
16 April	partly sunny, calm	0745	10.0	6.0	42	0800	10.0	5.5
	partly cloudy	2230	13.0	8.0		2230	13.0	5.5
17 April	sunny	0730	5.5	4.5	42	0738	5.5	5.0
	sunny	1833	12.0	9.0		1833	12.0	6.0
18 April	sunny	0730	8.0	6.5		0730	8.0	5.0
	sunny	1600	20.0	10.0				
	sunny	2015	12.0	5.0		2015	12.0	6.0
19 April	cloudy	0730	8.0	5.0		0730	8.0	5.5
	clear	1800	12.0	8.0		1810	12.0	6.0
20 April	cloudy	0730	7.0	6.0		0730	7.0	5.0
	partly cloudy	2200	9.0	7.0		2200	9.0	6.0
21 April	partly cloudy	0730	8.0	4.5		0730	8.0	6.0
	partly cloudy	1800	11.0	7.5		1800	11.0	6.0
22 April	rain	0730	5.5	4.5	51	0730	5.5	6.0
	rain	2100	9.0	5.0	51	2100	9.0	6.0
23 April	cloudy	0730	9.5	5.0	55	0730	9.5	6.0
	rain	2045	12.0	7.0	64	2000	12.0	6.0
24 April	rain	0730	8.0	4.5	68	0735	8.0	6.5
	rain	2045	10.0	4.5	73	2030	10.0	6.0
25 April	clear	0730	7.0	3.0	68	0735	7.0	6.0
	clear	2000	13.0	4.0	66	2000	13.0	6.0
26 April	high clouds, hazy	0830	7.0	3.5	70	0740	7.0	6.5
	hazy	2100	8.5	5.0	73	2100	8.5	6.5
27 April	clear	0730	4.5	3.5		0730	4.5	6.5
	hazy	2000	12.3	4.0	65	2000	12.3	6.5
28 April	fog	0730	8.5	4.5	65	0730	8.5	5.5
29 April	low cloud	0730	8.0	4.5	68	0730	8.0	6.5
	low cloud	1800	11.0	6.5				
30 April	mostly sunny	0730	10.0	4.5	72	0730	10.0	7.0
	mostly sunny	2100	14.0	6.5	72			
1 May	clear	0730	10.0	5.0	120	0730	10.0	7.0
	clear	1845	14.5	4.0	120	1950	14.5	6.5
2 May	cloudy	0800	9.0	3.0	110	0800	9.0	5.0
	cloudy	1800	11.0	4.0	100			
3 May	partly sunny	0800	6.0	3.5	90	0800	9.0	6.5
	partly sunny	1630	12.0	4.5	95			
4 May	low cloud	0730	4.0	3.5	75	0800	4.0	6.5
	low cloud	1800	6.0	5.0	70			
5 May	fog	0800	8.0	4.0	70	0800	8.0	7.0
	fog	1800	13.0	6.0	65	2200	8.0	6.0
6 May	low cloud	0830	7.0	4.5	65	0830	7.0	6.5
	low cloud	2000	6.0	5.5	65			
7 May	partly cloudy	0830	4.0	4.0	65	0830	4.0	6.5
	partly cloudy	1800	15.0	7.5	65			
8 May	partly cloudy	0800	5.0	4.5	65			
16 May	sunny	1330	18.0	7.0	80	1800	20.0	7.5

Table E.2. Water temperatures in Champion Creek, China Creek, Blueberry Creek, and Murphy Creek, spring 1981.

Date	Time	Water Temperature (°C)
<u>Champion Creek</u>		
15 April	1530	5.0
16 April	1600	4.0
17 April	1530	5.0
18 April	1130	4.5
19 April	1100	4.5
20 April	1520	4.0
21 April	1700	4.5
22 April	1245	4.5
24 April	1030	4.5
25 April	1630	4.5
26 April	1530	4.5
27 April	1300	5.0
28 April	1300	4.5
29 April	1430	5.0
30 April	1240	6.5
1 May	1445	5.5
2 May	1030	4.5
4 May	1020	4.0
5 May	0945	5.0
6 May	1400	5.0
7 May	1445	7.0
<u>China Creek</u>		
19 April	1330	5.5
30 April	1540	7.0
6 May	1340	6.0
<u>Blueberry Creek</u>		
20 April	1100	4.5
30 April	1530	7.0
6 May	1350	6.0
<u>Murphy Creek</u>		
19 April	1600	6.5
30 April	1550	7.0
6 May	1320	5.5

Appendix F
HABITAT EVALUATION PROCEDURE
AND RESULTS

HABITAT EVALUATION PROCEDURE (H.E.P.)

Western Energy and Land Use Team (W.E.L.U.T.)
U.S. Fish and Wildlife Service
Fort Collins, Colorado

The H.E.P. system utilizes a systematic species-habitat approach to determination of habitat suitability. The procedure has been under development since 1974. The H.E.P. format was initially released in 1976 and subsequently redefined in 1980. The system involves the following steps.

1. *Definition of the study area.* It is important to define at the onset the zone of influence to be considered (i.e., extent of contiguous areas to be assessed).
2. *Delineation of the various habitat cover types in the study area.* A cover type defines a homogeneous set of habitat conditions (e.g., riffle/run stream section).
3. *Selection of suitable evaluation species and evaluation criteria.* Evaluation species are selected on the basis of their ecological significance, their economic importance, the fact that they can serve as an indicator species for a larger group (i.e., guild approach), or because their preferred habitats are well documented. Evaluation criteria are selected on the basis of their ecological significance.
4. *Selection of an appropriate model to determine habitat suitability indices (HSI).* The ideal goal of the HSI model is to produce an index with a proven, quantified, positive relationship to carrying capacity. The model employed will depend on the scope of the study and the level of baseline information (i.e., narrative model, simple mathematical model, complex computer model).

$$HSI = \frac{\text{study area habitat conditions}}{\text{optimum habitat conditions}}$$

[Range 0.0 (nil) - 1.0 (optimum)]

5. *Calculation of the number of habitat units (HU) in the study area for each evaluation species.* An HU is equivalent to one unit (i.e., km, acre, hectare) of optimum

habitat for a given evaluation element (e.g., rainbow trout).

$$\text{HU} = \frac{\text{Total available habitat}}{\text{(Carrying capacity)}} \times \frac{\text{HSI}}{\text{(quantity) (quality)}}$$

The H.E.P., which is now a dominant methodology in the United States, has a number of advantages over existing techniques.

1. It provides a systematic accounting system for incorporating both quantitative and qualitative components into a habitat assessment.
2. It can be applied at any level of intensity in response to time, budgetary, or data constraints.
3. It provides a framework for more detailed assessment at a later date.
4. It is designed to incorporate existing data derived from regionally acceptable habitat classification schemes.
5. It provides a means of generating reproducible and documented results.
6. It can be used to compare habitat availability between areas under baseline conditions, to assess changes resulting from project actions, or as a basis for monitoring programs.
7. It allows for input from resource agencies and resource users in the early stages of the assessment (i.e., definition of the study area, evaluation species).
8. It provides the data necessary to establish monetary resource values [i.e., input into the Human Use and Economic Evaluation (H.U.E.E.) scheme].

Table F.1. Narrative model (from Neuman and Newcombe 1977) of salmonid habitat requirements used to determine habitat suitability indices (HSI).

Adult Migration:	Adult migratory salmonids require sufficient streamflow to allow passage over both shallow bars and obstructions such as falls. Low flows can affect fish passage in a number of ways. The most obvious of these is a delay or block in migration which depletes energy reserves and increases stress. If the block is of sufficient duration, fish may be in such poor condition that they are incapable of reaching the spawning grounds or of spawning successfully once they do arrive. Depth is probably the most serious limitation to fish passage during periods of reduced flow.
Spawning:	Spawning salmonids have at least three basic requirements which are affected by low flow. These are gravel composition, water depth, and water velocity. The spawning bed must be composed of gravel within a suitable size range if egg incubation and fry emergence is to be successful. The gravel must be free of fine sand, silt, and clay to ensure adequate water percolation around the eggs and to create intra-gravel spaces for the fry to move from the gravel into the stream. On the other hand, gravel must be small enough to enable the female to move it during nest building. Water velocity is probably the most important requirement of spawning fish. The female excavates a nest with her tail, and gravel is raised off the stream bottom where it is moved by current slightly downstream of the nest site. The current must be strong enough to move the gravel but not so strong as to require excessive energy expenditure by the spawning pair to remain over the nest. Depth is important to spawning and minimum depths exist for each species. Maximum depths do not seem as important since salmon have been observed to spawn in depths up to 7 m (24 ft.). Reduced stream flows can affect all of these spawning requirements. Low flows may dewater some spawning areas, and may prevent access to others. Similarly, accessible areas may not be suitable for spawning due to unacceptable depths and water velocities. A reduction in the spawning area not only limits the space available for egg deposition but also reduces spawning efficiency due to redd superimposition and stress resulting from an increased density of spawners.
Incubation:	Successful egg incubation and fry emergence depends on adequate percolation of high quality water through the gravel. An adequate oxygen supply is essential and is influenced by both high and low flows. High flows increase the sediment load of stream water and cause sedimentation, thereby inhibiting percolation and reducing the available oxygen. Low flows also reduce percolation rate. Freshets often scour the spawning beds and wash away redds, while low flows may dry up redds on the periphery of spawning areas.
Rearing:	Juvenile rearing is perhaps the most vulnerable phase of the salmonid life-cycle and rearing requirements are the most difficult to understand. Some salmonids like chum, pike, sockeye salmon, and kokanee migrate directly to the ocean or a lake, but others like trout, char, and coho salmon stay in streams for a few months to several years. Fish which rear in streams need an easily exploitable food source and adequate living space. Production of benthic invertebrates occurs mainly in riffles and fish usually stay in pools to feed. Thus, a riffle:pool sequence is a basic requirement of productive salmon streams. Stream substrate is important to insect production and is believed by some authors to be the most important factor affecting the distribution and abundance of bottom organisms. Although substrate type is related to flow characteristics, it is not affected by low flow and is, therefore, of little consequence to low flow studies. Several investigators consider depth to be important to insect production but the authors rarely state reasons. The majority of bottom organisms are found in depths ranging from 7 to 15 cm. Water velocity appears to be the most important factor influencing the production of stream invertebrates and swift-water species have been shown to have specific velocity requirements. Oxygen exchange is probably the primary reason for the importance of current velocity. Many insects adapted to clinging in flowing water are forced to swim during periods of reduced current and large mortalities are almost certain (Hynes 1970). Other effects of velocity also play a role in insect production. There is a strong positive correlation between water velocity and the amount of insect drift. Thus, current velocity over riffles is of major importance to fish populations because drifting invertebrates often form the bulk of fish food. Salmon and trout require suitable living space which affords protection from predators and easy access to food while allowing energy conservation and growth. The potential carrying capacity of a stream is directly proportional to the number and diversity of suitable fish micro-habitats (Allen 1969). Velocity and cover are the prime factors influencing the number of fish micro-habitats. Water velocity must be low enough to allow fish to maintain a fixed position and obtain food from the drift with minimal energy expenditure. Velocity may further influence fish populations by modifying territory size through its effect on invertebrate drift. Increased drift rates accompany higher velocities and could reduce the amount of stream area required to obtain food. Thus, territory size is reduced and the carrying capacity of the stream is increased. Cover, both submerged and overhead (streambank vegetation), protects fish from predators and is a highly desirable feature of good fish habitat. Overhead cover helps to moderate changes in water temperature and is a source of terrestrial insects entering the stream. At low flow levels any changes in discharge will change the area covered by water and might also change the amount of cover.

Table F.2. Summary^a of baseline data used to determine habitat suitability indices (HSI).

Species (Life Stage)	Temperature Range (°C)	Velocity Range (m/s)	Depth Range (m)	Substrate Range (cm)	Comments	Source
Rainbow trout (spawning)	4.4-12.8	0.49-0.91	> 0.18		Deschutes R.	Smith (1973) Hunter (1973)
		0.5-0.9	1.75-2.0	0.5-10.0	Gerrard Stock	Hartman and Galbraith (1970)
	7.0-15.5	0.1-0.9	0.1-0.6	0.2-6.4		Bovee (1978) ^b
	5.0-10.0	0.6-0.9	0.25-0.75	0.5-6.0	Norns Creek	Present Study
(rearing)	5.0-22.0	0.0-0.6	0.1-0.6	0.01-12.0		Bovee (1978) ^b
		0.07-0.45	0.12-0.63		cover important	Irvine (1978)
		0.0-0.7	0.1-0.7	> 2.0	Champion Creek	Present study
Kokanee (spawning)		0.46-0.66	0.37-0.60			Delisle (1962)
		0.09-0.67	0.06-0.40		20-35 cm fish	Hunter (1975)
		0.14-0.73	> 0.06			Smith (1973)
	6.7-12.2	0.12-0.42	0.09-0.34			Hunter (1973)
	3.0-13.3	0.06-0.55	0.06-0.34	1.0-15.0		Bovee (1978) ^b
	9.0-14.0	0.25-0.7	0.15-0.65	0.1-10.0	Norns Creek	Present study

^a Table partially from Neuwman and Newcombe (1977).

^b Ranges taken where probability of use is > 0.2.

Table F.3. Habitat availability and suitability for salmonid (i.e., kokanee and rainbow trout)^a spawning and rearing in tributaries within the study area, 1980 and 1981.

Location (km)	Habitat Area ^g (m ²)	Predominant Cover Type	Suitability Indices for Spawning/Incubation			SHSI ^b	Suitability Indices for Rearing			RHSI ^c	Overall HSI ^d	HU ^e
			Velocity	Depth	Substrate		Velocity	Depth	Substrate			
Norns Cr.												
0-0.15	3300	riffle	.2	.8	.2	.4	.2	.3	.1	.2	.3	990
.15-.35	4400	run	.7	.8	.6	.7	.1	.3	.5	.3	.5	2200
.35-.38	660	pool	.6	.6	.5	.57	.8	.4	.7	.6	.6	396
.38-.50	2640	run	.8	.8	.9	.83	.4	.5	.4	.43	.42	1109
.50-.80	6600	run	.5	.7	.5	.57	.4	.3	.3	.33	.45	2970
.80-.90	2200	pool	.6	.8	.6	.67	.3	.5	.2	.33	.5	1100
.9-1.05	3300	riffle	.4	.6	.3	.43	.2	.3	.2	.23	.33	1089
1.05-1.15	2200	run	.9	.9	.9	.9	.3	.3	.3	.3	.6	1320
1.15-1.2	1100	riffle	.05	.5	.05	.2	.1	.1	.1	.1	.15	165
1.2	330	pool	.05	.4	.05	.17	.8	.8	.8	.8	.48	153
1.2-1.25	1100	run	.7	.8	.6	.7	.1	.2	.1	.13	.42	462
1.25-1.27	440	pool	.5	.7	.7	.63	.2	.1	.1	.13	.38	167
1.27-1.35	6160	run	.7	.8	.6	.7	.1	.1	.1	.1	.4	2464
1.35-1.65	2200	riffle	.4	.7	.2	.43	.1	.1	.2	.13	.28	616
1.65-1.7	1100	run	.9	.9	.9	.9	.3	.3	.3	.3	.6	660
1.7-1.75	1100	riffle	.05	.1	.06	.07	.05	.05	.05	.05	.06	56
1.75-1.86	2420	riffle/pool	.5	.8	.4	.45	.2	.2	.1	.16	.36	871
1.86-2.2	7480	cascade	.05	.1	.1	.08	.2	.2	.2	.2	.14	1047
Total	48730											17950
Champion Cr. ^f												
0-0.6	4200	run	.2	.7	.2	.37	.8	.6	.6	.67	.55	2310
0.6-1.0	2900	run/riffle	.5	.7	.2	.47	.8	.6	.5	.63	.55	1540
1.0-1.6	4200	riffle/pool	.7	.7	.5	.68	.8	.8	.7	.77	.75	3150
1.6-2.5	5300	riffle/cascade	.05	.5	.02	.19	.1	.6	.1	.2	.25	1575
Total	17500											9575
Murphy Cr.												
0-0.6	5400	cascade/riffle	.1	.5	.1	.23	.5	.6	.4	.5	.3	1620
0.6-1.3	6300	cascade	.2	.6	.1	.3	.6	.8	.7	.7	.5	3150
1.3-1.7	3600	riffle	.3	.8	.2	.43	.7	.8	.7	.73	.6	1800
Total	15300											6570
China Cr.												
0-0.5	4000	run	.2	.5	.3	.33	.6	.7	.7	.67	.5	2000
0.5-1.7	9600	cascade	.1	.6	.1	.27	.1	.6	.2	.3	.3	2880
Total	10000											4880
Blueberry Cr.												
0-0.56	5040	run	.2	.5	.2	.3	.2	.4	.1	.23	.27	1361
0.56-0.65	810	run	.7	.7	.7	.7	.7	.7	.7	.7	.7	567
0.65-0.9	2250	run/flat	.5	.6	.5	.53	.5	.5	.5	.5	.52	1170
0.9-0.95	450	flat/run	.7	.8	.5	.67	.7	.8	.8	.77	.72	324
0.95-1.5	4950	riffle	.1	.1	.1	.1	.1	.1	.1	.1	.1	495
1.5-1.7	1800	run	.4	.6	.3	.43	.5	.9	.4	.57	.33	594
1.7-2.5	7200	cascade	.5	.7	.3	.5	.6	.6	.6	.6	.55	3960
Total	22500											3471

^aIn analysis the habitat suitability for rainbow trout and kokanee life requisites were combined. Different flows in spring and fall generally resulted in changes in temperature, velocity, and depth corresponding to differences in the requirements of these species (i.e., a specific cover type providing excellent spawning habitat for rainbow trout in the spring generally provided excellent spawning habitat for kokanee in the fall).

^bSpawning/Incubation Habitat Suitability Index (SHSI) = $\frac{\text{velocity} + \text{depth} + \text{substrate}}{3}$

^cRearing Habitat Suitability Index (RHSI) = $\frac{\text{velocity} + \text{depth} + \text{substrate}}{3}$

^dOverall Habitat Suitability Index (HSI) = $\frac{\text{SHSI} + \text{RHSI}}{2}$

^eHU (habitat units) = Overall HSI x area

^fIn 1980, Champion Creek was inaccessible to kokanee; therefore, the determination of habitat suitability and availability is for rainbow trout only.

^gMean channel widths of tributaries used to determine available area: Norns Creek - 22 m; Champion Creek - 7 m; Murphy Creek - 9 m; China Creek - 8 m; Blueberry Creek - 9 m.

Appendix G

AREA AND STORAGE CAPACITY OF THE MURPHY CREEK
RESERVOIR

Table G.1. Area and storage capacity of the Murphy Creek reservoir.

Headpond Elevation (m)	Area (ha)	Storage Capacity (m ³ x 10 ⁶)	Headpond Elevation (m)	Area (ha)	Storage Capacity (m ³ x 10 ⁶)
			420.0	1052	95.0
			419.7	1035	91.8
			419.4	1020	88.7
			419.1	1004	85.6
			418.8	987	82.5
			418.5	971	79.6
424.0	1319	141.8	418.2	955	76.6
423.7	1299	137.9	417.9	939	73.8
423.4	1279	133.9	417.6	923	70.9
423.1	1254	130.1	414.5	761	45.3
422.8	1234	126.3	411.5	579	24.8
422.5	1214	122.6	408.4	397	10.0
422.1	1194	118.9	405.4	263	0
421.8	1170	115.3			
421.5	1149	111.8			
421.2	1129	108.3			
420.9	1109	104.3			
420.6	1085	101.5			
420.3	1068	98.2			

Source: B.C. Hydro, unpublished data.

Appendix H

ANGLER USE AND HARVEST OF FISH
ON THE COLUMBIA RIVER, KEENLEYSIDE
DAM - TRAIL 1980-81

B.C. FISH AND WILDLIFE BRANCH
NELSON, B.C.

1981

TABLE OF CONTENTS

1. Introduction	1
2. Description of Study Area	2
3. Description of Methods	2
4. Figure 1. Columbia River downstream of Keenleyside dam	3
5. Results	
a) annual angler effort and catch	5
b) rainbow trout	5
c) Dolly Varden	7
d) kokanee	8
e) burbot	9
f) walleye	9
g) sturgeon	9
h) other species	10
6. Summary	10
7. References Cited	
8. Appendices	
i) Daily creel census sheet	
ii) Census summary sheet	
iii) Angler effort and catch May-October, 1980 - Columbia River, Keenleyside dam - Trail	
iv) Angler effort and catch March-May, 1981 - Columbia River, Keenleyside dam - Trail	
v) Angler effort and catch January-March, 1976 Columbia River, Keenleyside dam - Castlegar Ferry	

INTRODUCTION

The potential for hydroelectric dam sites on the lower Columbia River were first recognized during the early 1950's. Construction of the Mica, Libby, Duncan and Keenleyside dams upstream (Figure 1) have made a dam at Murphy Creek feasible. The dam site is located approximately 3 km upstream from Trail. If built, the resulting reservoir would inundate the Columbia River 35 km upstream to the base of the Keenleyside dam.

As a part of the effort to establish a baseline fisheries inventory in this area, B.C. Hydro and Power Authority has provided funds to the British Columbia Fish and Wildlife Branch to conduct a creel census to collect data on angler use.

Prior to this study, little information was available on the sportfishery of the Columbia River downstream of the Keenleyside dam. It was known that a mixed sportfishery existed for rainbow trout, Dolly Varden, kokanee, whitefish and burbot. Local anglers had also reported the occasional catch of sturgeon, walleye and chinook salmon. This report deals with creek census information obtained during the months of May-October, 1980 and March-May, 1981.

DESCRIPTION OF STUDY AREA

For the purposes of ^{is} these study, anglers fishing anywhere along the Columbia River (Figure 1) from Keenleyside dam downstream to Trail, B.C. were interviewed. The Kootenay River from Brilliant dam downstream to its confluence with the Columbia River (about 1 km) was not included due to difficulties of access and assumed minimal fishing effort.

DESCRIPTION OF METHODS

Data were collected by roving creel census clerks utilizing a combination of jet-powered boat and/or truck to interview anglers the length of the study area. Information collected included the number of anglers, species sought, number of fishing rods, the length of time spent fishing and place of residence as well as a sample of fish lengths, weights and scales from the anglers' catch.

The creel census was carried out eight days per month. Check days were stratified into four classes to account for day of week variation in angling effort. Two Saturdays, two Sundays, three weekdays and one Monday were "randomly" selected in advance using a table of random numbers. In such a program 100% coverage (i.e. all anglers for a total day) is sought but virtually never achieved. An estimate of percent coverage is therefore required to provide a total estimate of effort and catch.

Since each census day is a sample representing a particular day class within a one month period, the estimated monthly figures for each day class is obtained by multiplying the census day figures by the number of days of the class in the particular month.

eg. If there are 5 Sundays in the month, multiply the actual check data by 5.



Fig. 1. Columbia River downstream of Keenleyside Dam.

- 4 -

In the case of weekdays, (excluding Monday) each day represents 1/16 of the total number of days in that month (assuming 16 weekdays). If two weekdays are sampled, then one can either multiply the results of each of the day's data by 8 and add together, or; take the mean of the two days' data and multiply by 16 to estimate the total weekday results for the month.

Results for each species sought is totalled separately to give monthly harvest and effort results. Fishing success (catch per unit of effort CPUE) is simply the product of dividing the total catch estimates by the total effort (rod hours). This census method is used throughout the Kootenays by the Fish and Wildlife Branch and it has been adopted by most other Fish and Wildlife regions.

Samples of daily census sheets and summary sheets are displayed in appendices i and ii.

Sturgeon sportfishery data were obtained from a compulsory return card system. Each angler is entitled by permit issued by the Fish and Wildlife Branch to keep one sturgeon per year provided it is greater than 100 cm. A condition of the permit requires every angler to report his effort and catch for the year.

RESULTSa) Annual effort and catch

Fishermen utilized the entire length of the river from Keenleyside dam downstream to Trail. Angler effort was greatest during July and August with most anglers concentrated in the first 6-7 km below the Keenleyside dam. However, it is difficult to generalize in view of the variety of fish species sought and seasonal availability. Fishermen tended to seek burbot, Dolly Varden and kokanee in the upper portion of the river whereas rainbow were sought throughout the entire study area. Dolly Varden and rainbows were sought from May-October whereas kokanee and ling were sought primarily in the early spring and early summer months.

It became apparent to the fisheries technicians that good coverage of all anglers on such a long stretch of river within one day was difficult and that their efficiency was no greater than 60%. Further, because of the use of a roving creel census, anglers were not interviewed at the end of their fishing day. Due to this, fact the apparent number of hours per angler day was low - 1.29 hours - compared to 4.0 for Kootenay Lake (Andrusak, 1980) and 4.2 for Flathead River (Hanzel, 1977). To some extent the low number of hours per angler day may also be indicative of high local angler use. Total estimate of angler catch and effort, shown in appendices III and IV, have been adjusted to the 100% level.

The months of November - February were not checked during this program. However, during these months effort would not likely have exceeded 700 rod hours per month (500 angler days per month). Assuming this level of effort, annual angler use was estimated (Table I). Accounting for a 40% inefficiency inherent to this program, total angler days would be approximately 13,940 and effort would be 20,063 hours.

b) Rainbow trout

Clearly the greatest amount of effort was directed towards rainbow fishing. Perhaps the most obvious result of the census was the degree of good fishing for

TABLE I

Estimated annual angler days and rod hours, Columbia River,
Keenleyside dam to Trail, 1980-81

	<u>Angler Days</u>	<u>Rod Hours</u>
January*	500	700
February*	500	700
March	549	1,298
April	542	935
May**	865	1,045
June	734	1,360
July	1,252	1,677
August	1,275	2,085
September	636	666
October	511	484
November*	500	700
December*	500	700
TOTAL	8,364	12,050
Adjusted by 40%	13,940	20,083

* estimated made on the basis of seasonal trend.

** mean of May 1980 and 1981 census data

rainbow trout. Indeed, it is quite surprising that catch per unit effort (rainbow per rod hour), which ranged from 0.05-0.48, was anywhere near that level. Over the duration of the census success rate averaged 0.18 which is high for a river fishery. The average size of fish was nearly 1 kg but the opportunity existed for catching fish to 4 kg in size. In the spring months, rainbow fishermen used single lures such as "crocodiles" and "kanloopers", but as summer advanced flyfishing became the dominant method. In fact, during August and September fishing was largely restricted to early morning and evening fishing with little effort during the day. Dry flyfishing just at dusk produced some very pleasant fishing. Most rainbow were caught immediately below the Keenleyside dam and downstream of Castlegar ferry. Other popular spots for rainbow were at the mouth of Sullivan Creek and Norms (Pass) Creek.

A high percentage of fish caught in the vicinity of the ferry and Pass Creek during May-June were mature fish. Observations by the fisheries technicians, consulting biologists and that of other fish and Wildlife Branch staff lead to the conclusion that some trout spawn in the Columbia River between the ferry and Norms Creek. Biological data such as length, weight and age were collected from angler-caught fish and will be reported separately (S. Ash, pers. comm.). It is of interest to note that most spawners were 3-5 years old and that the majority of fish caught in the summer months were aged 3- and 4- years. As the summer advanced 2- fish were recruited into the fishery.

The actual estimated rainbow catch for the 8 months covered by the census was slightly over 1,500. Assuming a catch of 70 fish per month from November-February and adjusting the total by 40% the annual rainbow harvest approximates 2,150 fish per year.

a) Dolly Varden

Dolly Varden were the second most sought species next to rainbow trout. However, in contrast to rainbow, Dolly Varden success was very low (0-0.33 fish per hour) and on scheduled census days, only 5 fish were actually checked. Apparently fishermen were

willing to spend the time to fish for Dolly Varden in spite of low success because the possibility existed of catching a large fish (eg. 2-6 kg). Virtually all fishing effort for Dolly Varden occurred immediately below the Keenleyside dam. It is believed that a few large Dolly Varden move into the area below the dam during the spring in what is probably the remnants of a formerly large spawning population which inhabit the Roosevelt reservoir in Washington.

The annual harvest of Dolly Varden is probably less than 100 fish per year.

d) Kokanee

Kokanee are known to exist below the Keenleyside dam (dam to Robson ferry) in relatively large numbers. It is also known that a few kokanee can be found in large pools downstream of Castlegar but by far the majority of kokanee caught in the fishery are those below the dam. Most kokanee fishing is conducted from boats with preferred gear of either gang trolls or spin casting using lures such as "deadly dicks".

During 1980, angler success was highest in early summer. As the summer advanced the majority of kokanee in the fishery matured and moved to tributary streams to spawn thus becoming unavailable to fishermen. This explains the decline in catch and success during the months of August-October.

In 1979, kokanee fishing below Keenleyside dam was best in the winter and spring months. High success rates (Appendix V) for large kokanee (2-3.5 kg) were recorded and more intensive winter kokanee fisheries were known to have occurred in 1977 and 1978. For this reason the 1980 census program recommenced from March-May, '81 anticipating a repeat of this fishery. As shown in Appendix III there was virtually no kokanee fishing from March-May, 1981. The possible causes for this are discussed later in this report.

Twenty-five kokanee checked in May-June were weighed, measured and scales taken for age determination. Size ranged from 19-44 cm; eighty-eight percent were aged as 1+ with the remainder as 2+. The older fish (2+) were mature and would have spawned in late August. It is known that kokanee below the Keenleyside dam can grow to 3.5 kg in

size largely due to the availability of Mysis relicta being displaced out of the Arrow reservoir (data on file, Nelson F & W).

Based on the 1980/81 census data, the annual harvest of kokanee was less than 1,000.

e) Burbot

A modest number of anglers specifically fished for burbot immediately downstream of the dam. Only during March, 1981 was there any appreciable effort and high catch of ling. This fishery seems quite dependent upon constant discharge from the dam. Burbot are bottom dwelling fish which are quite stationary - at least during the day. Once located they are relatively easy to catch. However, changing water levels due to variable discharge from the dam undoubtedly results in these fish changing their location presumably in response to changing water currents hence food supply.

Based on the 1980/81 census data, the annual harvest of burbot was less than 250 fish.

f) Walleye

Walleye are a new species of fish to the British Columbia portion of the Columbia River. They were introduced into Roosevelt reservoir by Washington State in the early 1970's. This species has now successfully migrated up the Columbia River into British Columbia. A few of these fish were checked near trail and also below the dam. Reports have been received of fish caught up to 3 kg in size and that they are available primarily towards the end of summer.

g) Sturgeon

White sturgeon inhabit the lower Columbia River where they are occasionally caught by experienced anglers. Although no sturgeon anglers or fish were checked during this census program fishing did occur within the study area. A summary of the last two years of data from the compulsory return card system follows:

Year	Number of permits	Mean number of days fished	Number of fish caught	% return
1979	57	9.2	6	58
1980	61	11.6	3	54

Fish and Wildlife personnel (W. Campbell Pers. Conn.) were aware of additional fish being caught but unreported and it is estimated that only 50% of the fish caught were actually reported. Two locations - Wanera dam site and Keenleyside dam - are the preferred sites for sturgeon fishing. A reasonable estimate of current total catch within the study area is 6 fish per year.

b) Other fish species

A few whitefish, chinook salmon and brown trout were checked during the course of the creel census. The chinook salmon were released into the Roosevelt reservoir by Washington State Fish and Game in the mid 1970's. Brown trout were originally stocked in the Kettle River system in the 1940's. Neither species are abundant in the Columbia River and they are usually caught accidentally by fishermen who are fishing for rainbow trout and kokanee.

SUMMARY

The purpose of this study was to obtain some measure of the amount of fishing and the kinds of sportfish caught in the Columbia River from the Keenleyside dam downstream to Trail, B.C. The results provide a reference enabling comparison with future surveys as well as with other river fisheries.

Based on census data for 3 months and an assumed level of effort for the remaining four months total annual angler use within the study area is currently about 13,940 angler days. The total estimated annual effort of 20,083 rod hours is believed to be

low due to the problem of covering within one day anglers spread out over nearly 35 km of river.

Three fish species - rainbow trout, kokanee and Dolly Varden - provided the majority of recreational fishing on the river. Rainbow success (summer months mean = 0.18) was surprisingly high for a river fishery and compares favorably with river steelhead fisheries such as those of the Campbell and Quinsan Rivers where success rates are less than 0.1 fish per hour (Hooton, 1978). The Kootenay River immediately downstream of Nelson yielded 0.24 rainbows per hour in 1972 (data on file, Nelson Fish and Wildlife) and this ratio would almost certainly be much lower in 1980. Rainbow fishing on the Columbia River was in fact better than that on the Lower Arrow in 1978 where the success was less than 0.1 fish per hour (Lindsay, 1979). Mason (1979 M.S) reports a summer fishery for rainbow trout on the Stellako River yielded a success ratio 0.5 fish per hour. This river fishery would be comparable to that on the Columbia River except for differences in size of river and average size of fish being much smaller (31 cm) in the Stellako River compared to the Columbia (36 cm). The current annual harvest of rainbow on the Columbia River downstream of the Keenleyside dam is estimated to be nearly 2,000.

Within the study area the estimated annual harvest of less than 100 Dolly Varden is probably realistic. It is believed that these fish are spawners migrating up the Columbia River from Roosevelt reservoir and that their numbers are few and probably diminishing.

The estimated annual harvest of kokanee of 1,000 fish for 1980-81 is almost certainly low. In view of an earlier census in 1976 (data on file) when 1,000 fish were caught in 3 winter months it is believed that a more realistic annual harvest would be approximately 4,000 fish.

Failure of the spring kokanee fishery to materialize in 1981 cannot be explained. It is not clear whether kokanee found below the Keenleyside dam are recruited from Jess Creek or whether they are displaced fish from the Lower Arrow. In light of the

proposed dam at Murphy Creek the question of where these kokanee come from clearly needs further investigation.

Sturgeon fishing is becoming increasingly popular on the Lower Columbia probably due to the unique size of the fish and their relatively rare numbers. Annual catch within the study area is currently about 6 fish per year. Recently, tag and release work on the river indicates a large number of these fish. In four days fishing downstream of Trail, 94 sturgeon were captured and 74 tagged and released (W. Campbell, B.C. Fish and Wildlife, Pers. Comm.). During this fishing, only three recaptures were made. In one fishing trip below the Keenleyside dam three sturgeon were captured and released. While this information is still piecemeal it is becoming evident that a large number of sturgeon inhabit the Columbia River within the study area.

Within the context of the West Kootenays the Columbia River is a very important fishing area which provides a rare opportunity to fish in a free flowing river. The river is becoming more and more popular each year for local anglers particularly for rainbow trout, kokanee and sturgeon. Poor fishing on the Lower Arrow for rainbow trout and a total closure for kokanee at Balfour on Kootenay Lake has caused local anglers to shift from their traditional fishing areas. In this regard the Columbia River has taken on added importance in the last few years.

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Appendix 1

AREA	DATE
RAINBOW	
SOUGHT	
No. Anglers	
No. Rods	
No. Angler Hrs.	
No. Rod Hrs.	
R	R
D	D
K	K
W	W
L	L
DOLLY VANDEN	
SOUGHT	
No. Anglers	
No. Rods	
No. Angler Hrs.	
No. Rod Hrs.	
R	R
D	D
K	K
W	W
L	L
MORANEE	
SOUGHT	
No. Anglers	
No. Rods	
No. Angler Hrs.	
No. Rod Hrs.	
R	R
D	D
K	K
W	W
L	L
WATERLISH	
SOUGHT	
No. Anglers	
No. Rods	
No. Angler Hrs.	
No. Rod Hrs.	
R	R
D	D
K	K
W	W
L	L
LING	
SOUGHT	
No. Anglers	
No. Rods	
No. Angler Hrs.	
No. Rod Hrs.	
R	R
D	D
K	K
W	W
L	L
RES.	
NR-C	
NR-A	

Appendix IIIDDOTENY LAKE CREEL CENSUSDATE:WEATHER:AREA:

Number of Anglers	No. of Rods	Hours Fished	Species Sought	Species Caught	Length (cm.)	Weight (gms.)	Scale Sample Number	Place of Residence
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								
One								

R Rainbow
D Dolly Varden
K Kokanee
W Whitefish
L Ling

Appendix III
ESTIMATED ANGLER USE AND HARVEST
Columbia River: Keenleyside Dam - Trail
1980

	Species Sought	Number of Anglers	Angler Hours	No. Rods	Rod Hours	Estimated Catch	Species Sought C/UE
MAY	RAINBOW	531 (172)	605 (180)	597 (173)	608 (180)	<u>277R</u> (73)	0.46
	DOLLY VARDEN	552 (155)	559 (161)	558 (156)	562 (161)	<u>60V</u> (2)	0.01
	KOKANEE	57 (21)	99 (38)	75 (24)	126 (43)	<u>75K</u> (20)	0.60
	LING	8 (2)	8 (2)	8 (2)	8 (2)	-	-
	TOTAL	1224	1279	1238	1304	366	0.28
JUNE	RAINBOW	482 (154)	612 (214)	488 (156)	615 (215)	<u>116R, 5ch</u> (32) 4w	0.19
	DOLLY VARDEN	161 (47)	167 (55)	161 (47)	167 (55)	<u>50V</u> (1)	0.03
	KOKANEE	75 (29)	238 (88)	85 (32)	252 (94)	<u>131K, 5R</u> (51)	0.50
	LING	16 (3)	16 (3)	16 (3)	16 (3)	<u>5L</u> (1)	0.31
	TOTAL	734	1049	750	1060	271	0.26
JULY	RAINBOW	808 (229)	912 (264)	814 (232)	918 (267)	<u>152R, 16W</u> (43)	0.17
	DOLLY VARDEN	203 (49)	141 (35)	203 (49)	141 (35)	-	-
	KOKANEE	237 (66)	598 (165)	245 (70)	610 (170)	<u>381K, 14R</u> (132) 34ch	0.62
	LING	4 (2)	8 (4)	4 (2)	8 (4)	-	-
	TOTAL	1252	1659	1266	1677	597	0.36

Appendix iii (con't)

ESTIMATED ANGLER USE AND HARVEST
Columbia River: Keenleyside Dam - Trail
1980

	Species Sought	Number of Anglers	Angler Hours	No. Rods	Rod Hours	Estimated Catch	Species Sought C/UE
A U G U S T	RAINBOW	1060 (285)	1820 (542)	1077 (289)	1841 (547)	<u>1718</u> , 3W1 (50)	0.09
	DOLLY VARDEN	148 (37)	145 (41)	148 (37)	145 (41)	-	-
	KOKANEE	67 (19)	94 (33)	75 (21)	99 (34)	<u>9K</u> (2)	0.09
	TOTAL	1275	2059	1300	2085	183	0.09
S E P T E M B E R	RAINBOW	405 (128)	459 (151)	409 (130)	470 (156)	<u>718</u> , 23W1 (28)	0.15
	DOLLY VARDEN	173 (52)	124 (37)	173 (52)	124 (37)	-	-
	KOKANEE	23 (8)	34 (12)	25 (9)	37 (13)	<u>4K</u> (2)	0.11
	WALLEYE	35 (14)	35 (14)	35 (14)	35 (14)	-	-
	TOTAL	636	652	642	666	98	0.15
O C T O B E R	RAINBOW	276 (80)	297 (85)	276 (80)	297 (85)	<u>428</u> (9)	0.14
	DOLLY VARDEN	214 (65)	173 (53)	214 (65)	173 (53)	-	-
	WALLEYE	21 (5)	14 (4)	21 (5)	14 (4)	-	-
	TOTAL	511	484	511	484	42	0.09
TOTAL May-Oct.		5632	7182	5707	7276	1557	0.21
Adjusted (40K)							
TOTAL May-Oct.		9387	11970	9512	12127	2595	0.21

Appendix iv

ESTIMATED ANGLER USE AND HARVEST
Columbia River: Keenleyside Dam - Trail
March - May, 1981

	Species Sought	Number of Anglers	Angler Hours	No. Rods	Rod Hours	Estimated Catch	Species Sought C/UE
M	RAINBOW	498 (146)	1141 (365)	498 (146)	1141 (365)	<u>54R</u> , 1CDV (25) 7 K	0.05
A	DOLLY VARDEN	18 (5)	9 (3)	18 (5)	9 (3)	-	-
R	KOKANEE	5 (2)	25 (10)	5 (2)	25 (10)	5K	-
C	LING	28 (7)	123 (26)	28 (7)	123 (26)	<u>177L</u> , 9DV (23)	1.43
	TOTAL	549	1298	549	1298	272	0.21
A	RAINBOW	540 (166)	935 (320)	540 (166)	935 (320)	<u>129R</u> , 8W (33)	0.13
P	DOLLY VARDEN	2 (1)	1 (1)	2 (1)	1 (1)		-
R	TOTAL	542	936	542	936	137	
I							
L							
M	RAINBOW	506 (133)	785 (203)	506 (133)	785 (203)	<u>65R</u>	0.08
A							
Y							

Appendix v

Table 1. Estimated Minimum Catch and Effort in the Columbia River
Below Keenleyside Dam, Castlegar
January - March, 1976
(Actual counts in parenthesis)

	Species Sought	Number of Anglers	Angler Hours	No. Rods	Rod Hours	Estimated Catch	Species Sought C/UE
J A N U A R Y	Rainbow & Dolly Varden	174 (31)	303 (60)	174 (31)	303 (60)	4R, 23D (1) (5)	.09
	Kokanee	183 (30)	387 (67)	285 (38)	387 (67)	355K, 53R, (52) (8) 10D (2)	.92
	TOTAL	357	690	459	690	445	.64
F E B R U A R Y	Rainbow & Dolly Varden	123 (26)	203 (46)	123 (26)	203 (46)	12R, 8D (3) (1) 4K (1)	.10
	Kokanee	289 (55)	620 (115)	297 (56)	620 (115)	210K, 43R (44) (8)	.34
	TOTAL	412	823	420	823	277	.34
M A R C H	Rainbow & Dolly Varden	183 (34)	342 (68)	183 (34)	342 (68)	57R, 9D, 4K (11) (1) (1)	.19
	Kokanee	299 (63)	543 (121)	316 (66)	543 (121)	368K, 32R, 8D (92) (8) (2) SW (2)	.68
	TOTAL	482	885	499	885	486	.55
TOTAL JANUARY - MARCH 1976		1251	2398	1378	2398	1208 941K 201R 56D 8W	.50

Appendix I
TERMS OF REFERENCE

SECTION I
FISH AND AQUATIC HABITATS

The study area for aquatic resources includes the Columbia River from the Hugh Keenlyside Dam downstream to Trail, the Kootenay River from Brilliant dam downstream to the Columbia River and all tributaries flowing into them.

(a) Inventory

1. Determine relative abundance of fish species residing in the study area.
2. Estimate seasonal abundance of the major fish species including important sport fish, in the study area.
3. Identify and map areas used for spawning and rearing in the study area and in the tributaries to it. Note areas of post development improved access and post development inundation.
4. Determine whether adult and juvenile fish in the area are residents or migrants from the Columbia River below Trail. Estimate numbers and timing of principal species of fish migrating past the damsite.
5. Co-operate in the planning and interpretation of water quality aspects of the project as they relate to aquatic resources.

(b) Effect of Development

1. Identify the impacts of the proposed project on the fish and aquatic resources within and downstream of the study area. Identify any future studies required to improve the accuracy of the predictions.

2. Identify feasible methods to mitigate or compensate any detrimental impacts from the project, including the effect of annual drawdown. .
3. Predict the impacts of the development on recreational utilization of the fisheries resource in the study area and downstream of it.
4. Interpret the impact of water quality parameters, as determined under Section C, on the aquatic resources and predict downstream effects.
5. Comment on the potential value of the reservoir for fish production and recreational fishing.

MURPHY CREEK FISHERIES STUDY
ADDENDUM REPORT -
SUMMER/FALL 1981 STUDIES

for

B.C. Hydro
Vancouver, British Columbia

by

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W. Luedke

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November 1981

(Revised January 1984)

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W. Luedke - Fisheries Technician
T. Clayton - Scale analysis
C. McLeod - Editor
M. Bergot - Typist
C. Cox - Typist.

TABLE OF CONTENTS

		Page
	LIST OF TABLES	iii
	LIST OF FIGURES	iv
	LIST OF PLATES	iv
	LIST OF APPENDICES	v
	SUMMARY	vi
1.0	INTRODUCTION	1
1.1	BACKGROUND	1
1.2	STUDY AREA	1
1.3	OBJECTIVES	4
2.0	METHODOLOGY	5
2.1	STUDY SCHEDULING	5
2.2	SOURCES OF BACKGROUND INFORMATION	5
2.3	LOGISTICS	5
2.4	FISH COLLECTION/ENUMERATION METHODS IN THE MAINSTEM COLUMBIA RIVER	6
2.4.1	Trap Nets	6
2.4.2	Gillnetting	6
2.4.3	Float Surveys	7
2.5	TRIBUTARY SURVEYS	7
2.5.1	Escapement Estimates	7
2.6	FISH MARKING	8
2.7	TISSUE SAMPLING FOR HEAVY METALS	8
2.8	LIFE HISTORY DATA	9
2.8.1	Collection Phase	9
2.8.2	Analysis Phase	9
2.9	KOKANEE SCALE STUDIES	10

	Page
3.0 RESULTS AND DISCUSSION	11
3.1 SPECIES COMPOSITION AND STATUS	11
3.1.1 Downstream Sampling Region	11
3.1.2 Upstream Sampling Region	11
3.2 KOKANEE	14
3.2.1 Distribution and Abundance in the Mainstem Columbia River—Late Summer/Fall 1981	14
3.2.2 Spawning	15
3.2.2.1 Norns Creek	15
3.2.2.2 Other Tributaries	21
3.2.2.3 Deer Creek	21
3.2.3 Life History	21
3.2.3.1 Norns Creek	21
3.2.3.2 Deer Creek	22
3.2.4 Scale Studies	22
3.2.5 Heavy Metal Analysis	26
3.3 WALLEYE	26
3.3.1 Distribution and Abundance	26
3.3.2 Movements	27
3.3.3 Spawning	27
3.3.4 Feeding Habits	28
3.4 OTHER SPECIES	28
3.4.1 White Sturgeon	28
3.4.2 Rainbow Trout	29
3.4.3 Mountain Whitefish	29
3.4.4 Other Species	30
4.0 EFFECT OF DEVELOPMENT	31
5.0 PLATES	33
6.0 LITERATURE CITED	36
APPENDICES	37

LIST OF TABLES

Table		Page
1	Numbers of fish captured or observed by various sampling methods and percentage composition of the total catch (by species) in the mainstem Columbia River downstream sampling region. 15 August to 6 September 1981	12
2	Numbers of fish captured or observed by various sampling methods and percentage composition of the total catch (by species) in the Columbia and Kootenay rivers upstream sampling region. 15 August to 6 September 1981	13
3	Number of kokanee spawners enumerated in Norns Creek in 1981	16
4	Number and frequency of kokanee redds observed in Norns Creek in 1981	19
5	Scale characteristics of kokanee from various locations in the Columbia River system, 1980 and 1981	24

LIST OF FIGURES

Figure		Page
1	Murphy Creek Fisheries Study, August-September 1981, downstream sampling region sample locations	2
2	Murphy Creek Fisheries Study, August-September 1981, upstream sampling region sample locations	3

LIST OF PLATES

Plate		Page
1	Looking downstream at trap net sites on the mainstem Columbia River. 19 August 1981	34
2	Trap net site (on left downstream bank) following overnight drop in water level. 20 August 1981	34
3	A large female kokanee found dead in Norns Creek (Km 1.1) on 25 August 1981	35
4	Kokanee spawners in Norns Creek (Km 1.23). 28 August 1981	35

LIST OF APPENDICES

Appendix		Page
A	Summary of fish captures and CUE, Columbia River, Fall 1981	36
B	Summary of tagging studies, Columbia River, Fall 1981	41
C	Kokanee Tissue Mercury Concentrations	44
D	Terms of Reference	46

SUMMARY

Field studies were conducted, in the period 15 August to 6 September 1981, to determine if kokanee or other sport fish species migrated upstream past the proposed Murphy Creek damsite on the mainstem Columbia River. Intensive sampling was conducted in regions upstream and downstream of the proposed damsite. Mainstem collections of kokanee by trap net were relatively unsuccessful. The earlier than usual timing of the Norns Creek spawning run may indicate that movement occurred through the downstream sampling region prior to commencement of sampling.

In 1981, the Norns Creek kokanee spawning run was estimated at between 550 and 600 individuals, considerably smaller than the 1977 parental run. The most probable source of Norns Creek kokanee is from Lake Roosevelt. This conclusion is based on analysis of scale, age, and growth characteristics of kokanee from Norns Creek, the Columbia River, Deer Creek, and Lake Roosevelt, as well as interpretation of sampling catches in the mainstem Columbia River.

The abundance of walleye in the gill net catches near Castlegar was substantially greater during the fall 1981 study period than during the fall 1980 period. The source of these fish also appears to be Lake Roosevelt, as indicated by the capture of individuals tagged in the Spokane River.

Rainbow trout that spawn in Norns Creek and Champion Creek exhibit post-spawning movements to areas below the proposed damsite. One Norns Creek rainbow trout has been recaptured in Lake Roosevelt.

Other species, including white sturgeon, Dolly Varden, and carp, also may also undertake migrations through the study area.

Construction of the proposed Murphy Creek Project on the mainstem Columbia River would result in a total blockage to upstream movement of kokanee and certain other sport fish species unless suitable mitigative measures are implemented.

1.0 INTRODUCTION

1.1 BACKGROUND

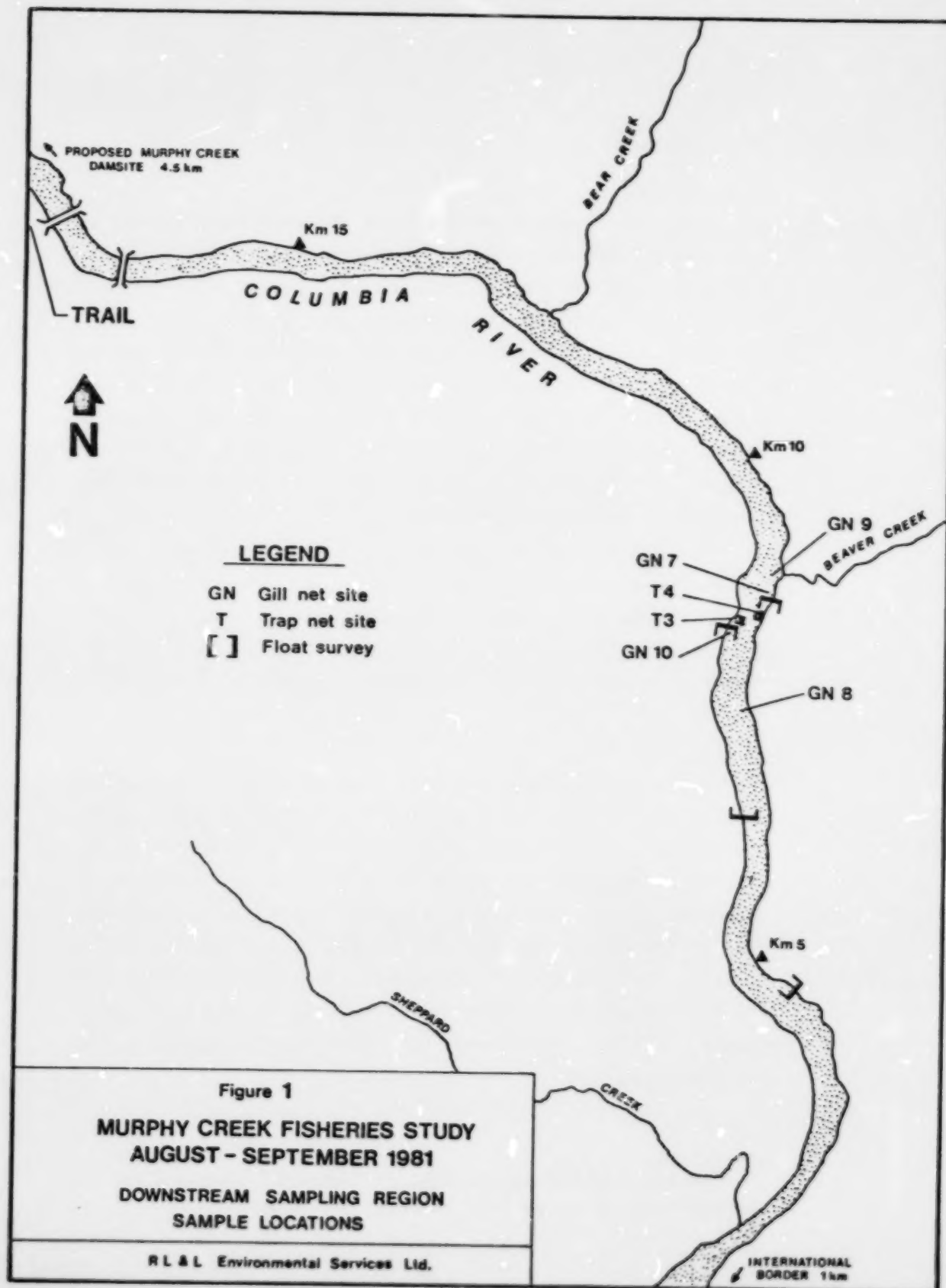
During the Murphy Creek fisheries studies, uncertainties arose as to the origin of the kokanee stocks spawning in Norns Creek. Available information suggested origins outside the study area. Firstly, there was a general absence of kokanee morphologically similar to Norns Creek spawners in the upstream region of the study area. Secondly, differences in scale characteristics suggested Norns Creek spawners were not a part of the local kokanee population in the mainstem Columbia River. Studies were required to document possible upstream migration of kokanee past the proposed Murphy Creek damsite (Km 22.5)^a and determine the probable source of these fish.

This addendum to the Main Report of the Murphy Creek Project - fisheries assessment, presents and discusses the results of studies conducted 15 August to 6 September 1981 by R.L. & L. Environmental Services Ltd. Interpretation of the results relative to the proposed project and post-project fishery also are presented.

1.2 STUDY AREA

The late summer/fall 1981 study was conducted in two distinct regions—one upstream of the proposed damsite and the other downstream of the damsite. The downstream sampling region was situated in the mainstem Columbia River between the Canada-United States of America International Boundary (Km 0) and Beaver Creek (Km 8.9) (Figure 1). The upstream sampling region consisted of the mainstem Columbia River at Castlegar (Km 45.5 to Km 56.2) (Figure 2) and major tributaries (Kootenay River, Norns Creek, Champion Creek, Blueberry Creek, China Creek, and Murphy Creek) upstream of the proposed damsite.

^aIn this report, distances along the mainstem Columbia River are given in kilometres upstream of the Canada-U.S.A. border.



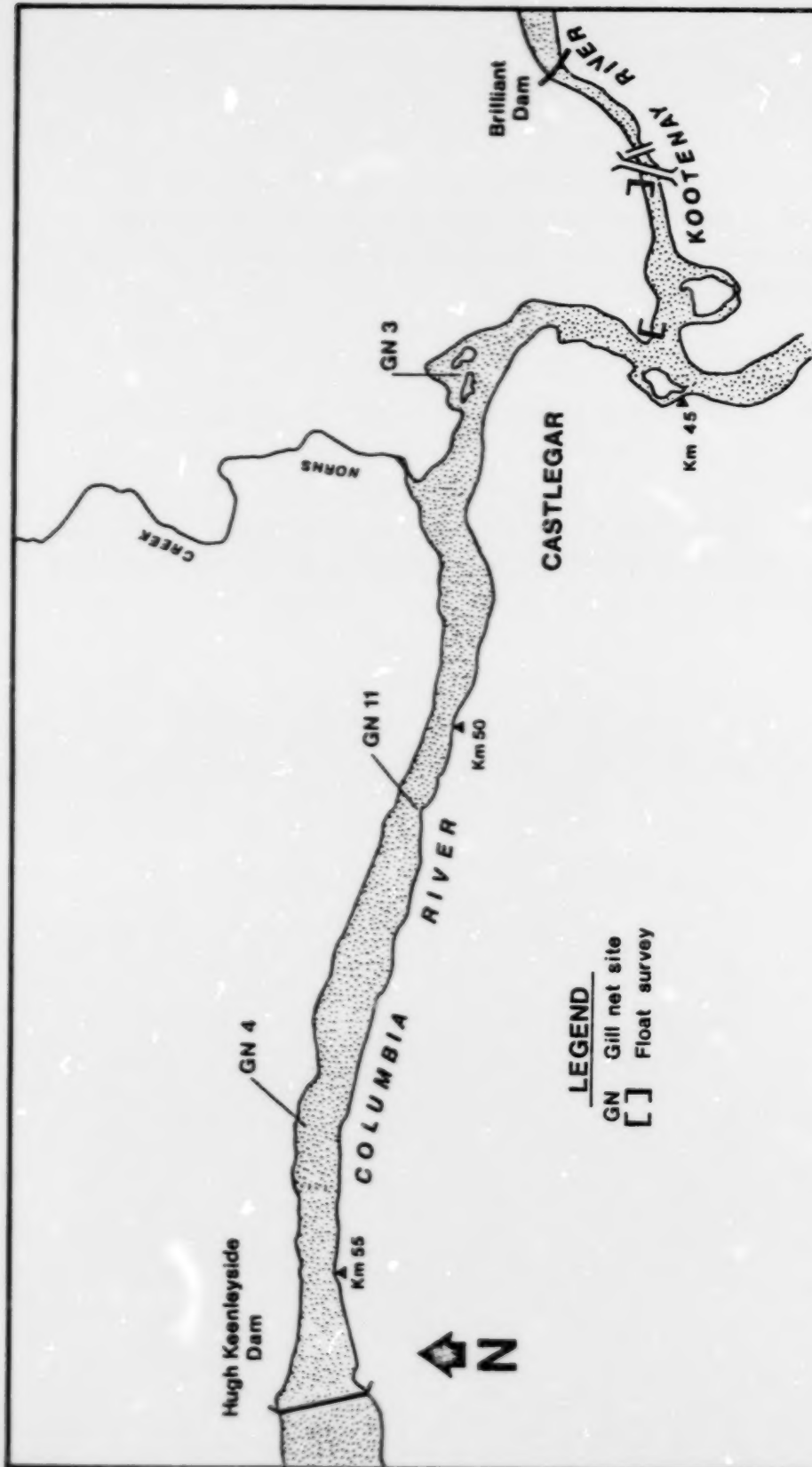


Figure 2
MURPHY CREEK FISHERIES STUDY
AUGUST - SEPTEMBER 1981
UPSTREAM SAMPLING REGION
SAMPLE LOCATIONS

RL & L Environmental Services Ltd.

In addition, the kokanee spawning run in Deer Creek (a tributary to Lower Arrow Lake, approximately 25 km upstream of Hugh Keenleyside Dam) was monitored to obtain kokanee samples for comparison with fish from Norns Creek.

1.3 OBJECTIVES

The objectives of this study were two-fold. Determination of the origin of the kokanee spawning in Norns Creek was a major objective. More specifically, this study attempted to identify and document possible upstream migration of kokanee or other species past the proposed damsite. A secondary objective was to document the extent of kokanee spawning within tributaries to the proposed Murphy Creek reservoir.

2.0 METHODOLOGY

2.1 STUDY SCHEDULING

Field investigations were conducted in the period 15 August to 6 September. The initiation of field studies was coincident with the estimated timing of a possible upstream migration of kokanee in the mainstem Columbia River. This estimation was based upon the timing of the 1980 kokanee spawning run in Norns Creek.

The investigations began with intensive sampling, using trap nets and gill nets, in the downstream region of the mainstem Columbia River, in an attempt to tag and release kokanee migrating upstream. As the spawning run in Norns Creek peaked, sampling intensity in the upstream region was increased.

2.2 SOURCES OF BACKGROUND INFORMATION

Background information was obtained from a variety of sources. Local fishermen provided information on fish distribution within the study area. The B.C. Fish and Wildlife Branch provided kokanee scale samples from Arrow Lakes, the Columbia River at Hugh Keenleyside Dam, and Norns Creek for comparison with scales obtained in this study. The U.S. Fish and Wildlife Service provided kokanee scale samples from Lake Roosevelt.

2.3 LOGISTICS

A two-man crew, based near Trail, was used during the field study. Sampling on the mainstem Columbia River was conducted from a Zodiac inflatable boat powered by a 20-hp motor. Suitable boat launching facilities were available at Beaver Creek (Km 8.9) and at Robson (Km 50.9).

2.4 FISH COLLECTION/ENUMERATION METHODS IN THE MAINSTEM COLUMBIA RIVER

2.4.1 TRAP NETS

The objective of the trap net program was to collect and tag as many fish as possible downstream of Trail, in hopes of recapturing tagged kokanee in Norns Creek. A 1.2-m by 3.0-m trap net was set on both the right and left sides of the mainstem Columbia River at Km 8.3 and Km 8.5, respectively (Figure 1). Two wings of 7.6-cm nylon mesh were attached to the trap. One, measuring 4.6-m long by 1.5-m deep, extended from the trap to shore. The other wing of similar mesh and depth, but 13.7-m long, stretched out from the trap at a downstream angle to the current. The effective sampling width of each of the traps was approximately 15 m. The location of one trap off a point bar extending into the main channel effectively increased this width to approximately 40 m. The trap nets were originally placed in 2 to 3 m of water but these depths were not maintained due to frequent fluctuations in water level; consequently, frequent repositioning was required. As a result of the water level fluctuations, the two trap nets were not effective methods of fish capture.

2.4.2 GILLNETTING

The gillnetting program was instituted to supplement trap net catches. The ease with which gill nets could be relocated allowed the sampling of habitats (e.g., deep pools, backeddies) not accessible by trap nets. Gill nets were used on a regular basis, although efficiency varied with fluctuating water levels and the amount of debris present.

Monofilament gill nets of various mesh sizes (3.8 cm, 6.4 cm, 8.9 cm, and 10.2 cm stretched measure) and consisting of 2.4-m by 15-m panels were employed during this study. Four gill net sites were established in the downstream sampling region (Figure 1). Three gill net sites (two of which were utilized in previous studies) were established in the upstream sampling region (Figure 2). Bottom sets were utilized more frequently than surface sets in anticipation of kokanee migrating in the lower velocity water along the bottom.

2.4.3 FLOAT SURVEYS

Selected areas within the Kootenay and Columbia rivers were visually assessed on longitudinal swim transects. Using a mask and snorkel, a swimmer floated downstream through river sections and visually identified and enumerated the fish present. Total observation time, length of channel surveyed, physical parameters, and fish observed were recorded upon completion of the transect. Due to the depth of the main channel throughout much of the Kootenay and Columbia rivers, this method was only useful near shore or over shallow (i.e., less than 4-m depth) areas of the mainstem.

A 2.5-km section of the Kootenay River was surveyed on 2 September 1981 (Figure 2). On 3 September 1981 float surveys were conducted on the Columbia River (Figure 1) along 4.1 km of the east side of the channel and 1.9 km of the west side of the channel.

2.5 TRIBUTARY SURVEYS

Tributary surveys were conducted to enumerate kokanee spawners and to determine habitat utilization and redd distribution. Spawning locations were confirmed by the presence of eggs in the substrate. Sampling for eggs was conducted by disturbing a small area of the substrate (approximately 0.5 m²) and collecting drifting eggs in a dip net positioned immediately downstream.

Kokanee found dead during surveys of the tributaries were collected and basic life history information, including length, weight, scales, and otoliths, was taken for life history analysis; carcasses not collected were marked to prevent recounting.

2.5.1 ESCAPEMENT ESTIMATES

Estimates of kokanee escapement into the Columbia River tributaries were based on visual enumerations. Two observers simultaneously walked the stream banks and enumerated the kokanee which were generally readily visible in the clear, shallow waters. These counts were

then averaged and a range obtained. Counts were conducted twice weekly during the spawning period.

2.6 FISH MARKING

A tagging program was conducted in the mainstem Columbia River to provide information on movements past the proposed damsite. Fish in good physical condition at the time of capture and exceeding 200 mm in length were marked with a labelled Floy FD67 Anchor Tag.^a The tag was inserted into the dorsal musculature immediately below the insertion of the dorsal fin and between the dorsal fin rays. A summary of the number of fish of each species tagged is presented in Appendix B.

2.7 TISSUE SAMPLING FOR HEAVY METALS

A heavy metals sampling program was conducted in conjunction with the B.C. Waste Management Branch. Tissue samples were taken from various species of fish in the upstream and downstream regions of the mainstem Columbia River. Tissue samples also were taken from Norns Creek and Deer Creek kokanee. The results of this program may also give insight into the origin of the Norns Creek kokanee. In 1980, heavy metal concentrations were significantly greater in fish sampled below Trail than in fish near Castlegar (B.C. Waste Management Branch, unpublished data). Therefore, higher concentrations of heavy metals in Norns Creek kokanee than in kokanee sampled near Castlegar or in Deer Creek may indicate origins below Trail.

The procedure involved in tissue sampling required safeguards (i.e., sterile instruments, tissue cups rinsed in acidic solution, and covering of hands and work area in plastic) to prevent contamination of the samples. Dorsal musculature (55 to 110 g) was dissected from each fish sampled,

^aLabelled "R.L.L." followed by a five-digit number.

and sealed in plastic tissue cups. Livers from each species were collectively sealed into a tissue cup. All samples were subsequently frozen.

Analysis of the samples to determine heavy metal concentrations was conducted by provincial and federal government agencies.

2.8 LIFE HISTORY DATA

2.8.1 COLLECTION PHASE

Pertinent life history data were collected from all fish captured in the upstream and downstream sampling regions; however, emphasis was placed on sport fish species. Fork length to the nearest millimetre was recorded and weight determined on a Chatillon Model 1038B spring scale (0 to 5000 g). Sex and maturity were determined by dissection, external examination, or (during spawning seasons) release of sexual products. Scales were collected from the area immediately below the anterior insertion of the dorsal fin on the left side of the fish and were placed in envelopes for later processing. Otoliths were dissected from selected individuals and stored dry. Stomach contents were examined cursorily in the field. All life history data were entered on fish data sheets for subsequent computer tabulation and analysis.

2.8.2 ANALYSIS PHASE

Fish aging was accomplished by mounting fish scales between glass microscope slides and viewing with a 3M Model SRC816 microfiche reader or a binocular dissecting microscope. Otoliths were cleared in 2% KOH and aged using a binocular dissecting microscope.

In this study, kokanee were assigned ages according to the "freshwater method" (i.e., age corresponds to the number of annuli) as opposed to the Gilbert system (i.e., the year of life and the number of years in freshwater are indicated). For example, a 2+ kokanee aged according to the freshwater method (two annuli and in its third year of life) corresponds to an age 3₃ fish in the Gilbert system. Kokanee scales which exhibited obvious resorption were not used in life history analyses.

2.9 KOKANEE SCALE STUDIES

Scale characteristics from kokanee captured in Deer Creek, the mainstem Columbia River at Castlegar, Norns Creek, and Lake Roosevelt were compared in an attempt to discern differences that might provide insight into the origin of Norns Creek kokanee. Scales were viewed using a 3M microfiche reader. The primary method of comparison used involved the counting of the number of circuli between the focus and the first annuli. Other parameters documented included a qualitative assessment of growth in the third summer, and the extent of resorption of the scale margin.

3.0 RESULTS AND DISCUSSION

3.1 SPECIES COMPOSITION AND STATUS

3.1.1 DOWNSTREAM SAMPLING REGION

In the period 16 August to 4 September 1981, 13 species of fish were encountered in the downstream sampling region. The percentage contribution of each species to the total catch is summarized in Table 1. A total of 1163 fish was captured or observed in this region of the mainstem Columbia River.

Eight species encountered were regarded as sport fish; they contributed over 32% to the total catch. Mountain whitefish were the most abundant sport fish, constituting 21.9% of the total catch. Walleye also were common, contributing 8.0% to the total catch. Other sport fish captured included kokanee, rainbow trout, Dolly Varden, lake whitefish, burbot, and white sturgeon.

Coarse fish species, including longnose and largescale suckers, northern squawfish, peamouth, and carp, constituted the major portion of the total catch (i.e., 68%). Catostomids (i.e., suckers) were the most abundant fish (i.e., 45.7% of the total number encountered). Peamouth and northern squawfish were prevalent also, contributing 12.6% and 6.1% to the total catch, respectively.

3.1.2 UPSTREAM SAMPLING REGION

Upstream of the proposed damsite, 11 species of fish were captured. Within the Kootenay River and Columbia River mainstems, a total of 287 fish was captured or observed. The general population status of the various fish species as indicated by their percentage composition to the catch is summarized in Table 2.

Seven species were regarded as sport fish. Mountain whitefish were the most abundant, constituting 26.5% of the total catch. Walleye were also a common sport fish, constituting 7.3% of the total catch and 24.1% of the total gill net catch. One white sturgeon, weighing approximately 18 kg, was captured at Km 51.5 of the Columbia River. Three mature kokanee also were captured.

Table 1. Numbers of fish captured or observed by various sampling methods and percentage composition of the total catch (by species) in the mainstem Columbia River downstream sampling region. 15 August to 6 September 1981.

Species	Species Code	Trap Net	Gill Net	Float Survey	Total Number	%
Kokanee	K		2		2	0.2
Rainbow trout	RT	1	11	1	13	1.1
Dolly Varden	DV		2	1	3	0.3
Mountain whitefish	MW	1	79	175	255	22.2
Lake whitefish	LW		4		4	0.3
Walleye	YW		48	45	93	8.0
Burbot	LING		1		1	0.1
Sucker sp.				475	475	40.8
Longnose sucker	LNS		23		23	2.0
Largescale sucker	LSS		34		34	2.9
Northern squawfish	NSF	3	8	60	71	6.1
Peamouth	PM		46	100	146	12.5
White sturgeon	WST		3		3	0.3
Carp	CARP			40	40	3.4
Total		5	261	897	1163	
Effort		33.4 d	24.9 NU ^a	6.2 km		
CUE (fish/unit effort)		0.15	10.5	144.7		

^a NU (net unit) = 100 m² net set for 24 hours.

Table 2. Numbers of fish captured or observed by various sampling methods and percentage composition of the total catch (by species) in the Columbia and Kootenay rivers upstream sampling region. 15 August to 6 September 1981.

Species	Species Code	Gill Net	Float Survey	Total Number	%
Kokanee	K	3		3	1.0
Dolly Varden	DV	2		2	0.7
Mountain whitefish	MW	26	50	76	26.5
Lake whitefish	LW	3		3	1.0
Walleye	YW	21		21	7.3
Burbot	LING	9		9	3.1
Sucker sp.			150	150	52.3
Longnose sucker	LNS	2		2	0.7
Bridgelip sucker	BLS	1		1	0.3
Largescale sucker	LSS	12		12	4.2
Northern squawfish	NSF	7		7	2.4
White sturgeon	WST	1		1	0.3
Total		87	200	287	
Effort		5.1 NU ^a	1.6 km		
CUE (fish/unit effort)		17.1	125		

^a NU (net unit) = 100 m² net set for 24 hours.

Coarse fish species collected in the upstream region include longnose, largescale, and bridgelip suckers, and northern squawfish. They constituted 59.5% of the total number of fish encountered (i.e., both gill nets and float survey).

3.2 KOKANEE

Kokanee were the object of an important sport fishery in the Columbia River between the Castlegar ferry and the Hugh Keenleyside Dam in previous years (B.C. Fish and Wildlife Branch 1981); however, reductions in sampling catches and angler success indicated a substantial reduction in abundance in the period 1980 to 1981. Similar reductions in kokanee populations in recent years have been noted in Lake Roosevelt (T. Nigro, U.S. Fish and Wildlife Service, pers. comm.) and in the Kootenay and Arrow lakes (H. Andrusak, B.C. Fish and Wildlife Branch, pers. comm.).

In the late summer/fall of 1980 kokanee spawning in the tributaries within the study area was monitored. Norns Creek supported a major spawning run, estimated to consist of 2000 fish. Two size classes, designated large and small, were observed. Inconclusive evidence suggested these kokanee originated outside the study area, likely from Lake Roosevelt in Washington. The fall 1981 study was conducted in an attempt to provide further evidence of the origin of the kokanee spawning in Norns Creek.

3.2.1 DISTRIBUTION AND ABUNDANCE IN THE MAINSTEM COLUMBIA RIVER—LATE SUMMER/FALL 1981

Large kokanee were absent from the downstream sample region trap net and gill net catches; however, one mature kokanee, similar in size to small spawners found in Norns Creek, was captured. This individual would have spawned in the 1981 period. The relevance of the absence of large kokanee in determining the presence of an upstream migration past the proposed damsite cannot be established with the available information (i.e., the absence may be a result of movement

through the area prior to commencement of sampling). The timing of the 1981 kokanee run into Norns Creek (i.e., approximately 1 to 2 weeks earlier than 1980) suggests the proposed migration up the Columbia River may have occurred prior to commencement of sampling in the downstream region, resulting in the absence of large kokanee from the catches.

In the upstream sampling region of the mainstem Columbia River, three large and mature kokanee were captured in gill nets. The presence of mature individuals upstream of Norns Creek in the 1980 and 1981 fall periods suggests spawning by this stock of kokanee also likely occurs in the mainstem.

The absence of juvenile kokanee in the catches of this region during the fall 1981 period reiterated the apparent reduction of kokanee abundance in the study area (discussed in the main report).

3.2.2 SPAWNING

3.2.2.1 Norns Creek

(a) Timing

The 1981 kokanee spawning run into Norns Creek commenced during the period 16-18 August. No kokanee were observed in a cursory survey conducted on 15 August; however, over 200 fish were enumerated on 19 August (Table 3). In previous years the kokanee run into Norns Creek has commenced in late August or early September, approximately 1 to 2 weeks later than observed in 1981. Available information gives no reasons for the early migration in 1981; however, this behaviour also was documented for the Kootenay Lake kokanee escapement to Meadow Creek in 1981 (W. Campbell, B.C. Fish and Wildlife Branch, pers. comm.).

Water temperatures in Norns Creek during the 1981 spawning period were generally higher than during the 1980 period. The mean afternoon water temperature during this study was 14.5°C, whereas the mean afternoon temperature during the 1980 spawning period was

Table 3. Number of kokanee spawners enumerated in Norns Creek in 1981.

Date	Water Temp. (°C)	Number ^a									
		Reach 1 ^b		Reach 2		Reach 3		Total		Total	
		Large ^c	Small	Large	Small	Large	Small	Large	Small	Large and small	Total
19 Aug.	15.5	21-25	0	70-75	15-20	93-118	2	184-218	17-22	201-240	
21 Aug.	16.0	42	2-5	244-254 (1)	33-35	99-134	12-16	385-430 (1)	47-56	432-486 (1)	
25 Aug.	16.0	34 (19)	0	209-214 (10)	33-34	79-85	25-30	322-333 (29)	58-64	380-397 (29)	
28 Aug.	16.0	28 (9)	9	218-248 (10)	25-30	35-40	30-35	281-316 (19)	64-74	345-390 (19)	
31 Aug.	13.0	22 (8)	0	344-374 (7)	55	15-17	24-27	381-413 (15)	79-82	400-495 (15)	
4 Sept.	12.0	32 (25)	0	327-335 (22)	45-50	8-10	17	367-377 (47)	62-67	429-444 (47)	
6 Sept.	12.0	23 (22)	0	263-275 (43)	32-35	2-3	5-8	288-301 (65)	37-43	325-344 (65)	

^aThe number of unmarked carcasses observed is given in brackets.^bReach 1 extends from the mouth to Km 1.05.

Reach 2 extends from Km 1.05 to Km 1.8.

Reach 3 extends from Km 1.8 to Km 2.2.

^cLarge and Small are designations of two kokanee sizes utilizing Norns Creek.

12.0°C. Scott and Crossman (1973) indicate that movement of kokanee into spawning streams occurs over a wide range of temperatures (10.5° to 15°C), turbidities, and water levels; thus, it is unlikely that the water temperature difference observed in 1981 significantly influenced their movements.

The first ripe and spent kokanee in Norns Creek appeared on 21 August, whereas in the 1980 study, spent individuals were first noted on 27 August.

(b) Escapement

An estimated 500 to 600 kokanee^a utilized Norns Creek in the period 19 August to 6 September (Table 3). This estimate was comprised of between 450 and 500 large kokanee (greater than 35-cm length) and between 75 and 100 small kokanee (less than 30 cm in length).

The 1981 spawning escapement was expected to be large, a cyclic response to the large number of kokanee that spawned in Norns Creek in 1977 (estimated to have been 5000 fish). The actual escapement in 1981 (i.e., between 550 and 600 kokanee) was much lower than expected, indicating high mortality at some stage of the life cycle.

A number of environmental factors may have contributed to the high mortality, including

- (1) possible low egg survival if large freshets occurred during the winter of 1977-78;
- (2) low fry and juvenile survival as a result of predation by species such as walleye, which have increased in abundance during recent years; and

^aCounting accuracy was affected by a number of factors. A decrease in water and air temperature and a reduction in the amount of human activity along the creek occurred on 30 August. Prior to this time the kokanee were generally concentrated in deep pools and along banks affording cover, resulting in a lower counting accuracy. After 30 August the kokanee were more evenly distributed across the channel, allowing more accurate enumeration. The highest count occurred on 31 August.

- (3) possibly greater than normal pre-spawning mortality as a result of outbreaks of disease caused by high water temperatures and other environmental conditions.

(c) Habitat Utilization

Kokanee were distributed throughout most of the creek; however, spawning activity was limited to specific areas. The greatest number of kokanee were consistently enumerated in Reach 2, extending from the Pass Creek Park intake at Km 1.05 to the base of the cascades at Km 1.8 (Table 3). More specifically, redd frequency (Table 4) indicates that Km 1.05 to Km 1.25, Km 1.70 to Km 1.75, and the left downstream channel at Km 1.8 are subject to high density utilization (i.e., more than 20 redds per 100 m of creek). Habitat in these preferred areas consisted of uniformly-sized gravel substrate (2 to 10 cm in diameter), depths ranging between 20 and 60 cm, and surface velocities ranging between 0.6 and 0.9 m/s. All areas were associated with pools or vegetated banks affording cover.

The absence of kokanee in some areas utilized during the 1980 spawning periods suggests marginal habitat in these areas (i.e., Km 0.5 to Km 0.7 and Km 1.25 to Km 1.70). The inundation and resulting siltation of Norns Creek to the bridge at Km 0.5 by high water levels in the mainstem Columbia River prevented the use of this area by spawning kokanee. No spawning activity was observed in Reach 3; the decreasing abundance of kokanee in this reach during the study period (Table 3) probably reflects initial movement as far upstream as possible with subsequent movement to more suitable spawning habitat in Reaches 1 and 2.

(d) Pre-spawning Mortality

Examination of dead spawners in the period 21 August to 31 August indicated a high pre-spawning mortality rate among large kokanee in Norns Creek. Of the 27 fish examined, 19 (70.4%) had died without spawning. Reasons for this high pre-spawning mortality can only be speculated. Lethal water temperatures for kokanee (i.e., probably above

Table 4. Number and frequency of kokanee reddsa observed in Norns Creek in 1981.

Date	Number and Frequency (No./100-m creek length)						Total
	Km 0.5- 1.05 ^b	Km 1.05- 1.25	Km 1.25- 1.70	Km 1.70- 1.75	Km 1.75- 1.79	Km 1.79- 1.86	Km 1.86- 2.2
21 Aug.	3 (0.6)	17 (6.8)		11 (22)		2 (2.9)	33
31 Aug.	19 (3.5)	59 (30)	2 (0.4)	15 (30)		19 (27)	114

^a Only redds made by large kokanee were distinct enough to be counted.

^b Kilometerage is the same used in the 1980 surveys. During the 1981 survey Norns Creek was inundated to the bridge at Km 0.5 by high water levels in the mainstem Columbia River.

20°C) were not present in the mainstem Columbia River or in Norns Creek; kokanee in this area do not travel distances extensive enough to severely affect their total energy consumption, and timing of the run did not indicate any delay or obstruction severe enough to result in pre-spawning mortalities.

During field studies it was noted that most dead kokanee displayed severe lesions of the body typical of pathogenic bacterial infection (Plate 3). Environmental conditions (i.e., high water temperatures, low dissolved oxygen levels, etc.) often trigger outbreaks of bacterial disease (Colgrove and Wood 1966; Bullock and McLaughlin 1970). Bacterial diseases expected in the Columbia River include furunculosis (*Aeromonas salmonicida*) and columnaris disease (*Chondrococcus columnaris*). *C. columnaris* is known as a "summer" disease as it has been observed only in warm weather (Colgrove and Wood 1966) and has caused severe pre-spawning mortalities in salmon (especially sockeye) in the Columbia River and Fraser River basins. Water temperatures in the mainstem Columbia River during this study averaged 16.5°C, sufficient for infection or transmittal of bacterial strains such as *C. columnaris*. Highly virulent strains of this bacteria can produce disease at temperatures as low as 10° to 15°C (Colgrove and Wood 1966). The gross pathology of the kokanee examined during this study appeared to support the possibility of infection by *C. columnaris*. Lesions of the body often begin as small, circular, eroded areas which may increase in size (Plate 3) and become subject to secondary infection (Colgrove and Wood 1966). Some dead spawners displayed no visible external body lesions; however, this also may have been caused by infection of *C. columnaris*, as this disease often infects the gill tissues and may be unobservable.

Detailed laboratory pathological studies would be required to identify specifically the bacterial disease present in kokanee or other fish in the area and the extent to which it contributes to the pre-spawning mortality of this species. The rapid mortality of kokanee in Norns Creek also suggests that some fish may have died prior to reaching the spawning grounds, thus reducing the total escapement.

3.2.2.2 Other Tributaries

No kokanee were observed in any of the other tributaries in the study area. Surveys were conducted twice weekly on Champion Creek, Blueberry Creek, China Creek, and Murphy Creek. Discharges and temperatures in these creeks were slightly higher during this study than during the fall 1980 study. These systems were more accessible to migrating fish than they were in September 1980 because much higher water levels in the mainstem Columbia river resulted in backflooding at the tributary mouths.

Kokanee were not observed in a float survey of the lower Kootenay River on 2 September. Potentially suitable spawning habitat observed consisted of a shoal near the highway bridge and a submerged gravel bar in mid channel near the confluence with the Columbia River; however, water level fluctuations over the winter may render these areas unsuitable for kokanee spawning.

3.2.2.3 Deer Creek

Deer Creek, a tributary to Lower Arrow Lake approximately 25 km upstream of Hugh Keenleyside Dam, is a major spawning stream for kokanee in Lower Arrow Lake. Kokanee spawning in this system was monitored to allow comparison of specific parameters (i.e., timing of spawning, size of spawners, scale characteristics, etc.) with kokanee in Norns Creek. Weekly surveys of Deer Creek indicated that the 1981 spawning run commenced in the last week of August. On 2 September 1981 an estimated 2000 kokanee were observed in the lower 0.5 km of the creek. At this point, a partial barrier, created by a 20-cm drop from a culvert at the main road crossing, inhibits upstream movement. Individuals are present above the culvert but at a much lower density.

3.2.3 LIFE HISTORY

3.2.3.1 Norns Creek

A total of 26 large kokanee from Norns Creek was sampled for life history information during the fall 1981 study. The range of fork lengths

encountered was 341 to 514 mm, with the mean being 459 mm. No sex-related differences in size were noted. The male/female sex ratio of the 26 kokanee sampled was 1.6:1. Of the sampled individuals, 7.7% were gravid, 61.5% ripe, and 30.8% spent.

Two small kokanee from Norns Creek also were sampled. Their fork lengths were 246 mm and 224 mm.

3.2.3.2 Deer Creek

A total of 30 kokanee from Deer Creek was sampled for life history information. The mean fork length of these fish was 225.8 mm, with a range of 205 to 260 mm. The male/female sex ratio was 2.3:1, with 50% of the sample gravid, 50% ripe, and none spent. The majority (73.3%) of the Deer Creek spawners were aged as 3+.

3.2.4 SCALE STUDIES

The scales of a salmonid species of fish are useful in the assessment of growth characteristics and provide evidence regarding the stock or racial origin of the fish sample. Henry (1961) described a method by which differences in the number of circuli in each growth zone were used to differentiate populations of Fraser River sockeye. Vernon (1957) successfully employed variations in the degree of scale resorption to separate kokanee from the West, North, and South arms of Kootenay Lake. A survey of methods of scale analysis used in determining origin of Pacific salmon (Major et al. 1970) indicated a relationship between the number of circuli in a growth zone and their environment.

A number of the methods presented in these studies were utilized in an attempt to determine the origin of the kokanee that spawn in Norns Creek. Scale samples from four areas (i.e., Deer Creek, the mainstem Columbia River at Castlegar, Norns Creek, and Lake Roosevelt) were examined and compared. The primary character used in differentiating these stocks was the number of circuli to the first annulus, counted on the posterior-lateral axis of the scale. The mean number of circuli present on the scales from the various samples of kokanee are presented

in Table 5. Additionally, the degree of scale resorption was noted. The spacing of circuli in later years also was noted in hopes of differentiating environments utilized; however, scale resorption often prevented this.

Because of the small sample sizes available for some of the kokanee populations (i.e., small kokanee in Norns Creek, kokanee from Lake Roosevelt), an assumption was made that sample sizes available accurately portray the characteristics of that group of kokanee. Analysis of the scales examined resulted in the following conclusions:

- (1) Two populations of kokanee utilize Norns Creek. These kokanee, formerly differentiated by size (i.e., large and small), also can be differentiated by the mean number of circuli. Although the small kokanee sample consisted of only two fish, there were significantly fewer circuli to the first annulus on scales of the small kokanee (i.e., $\bar{x} = 7.5$ circuli; $n = 2$) than on scales of the large kokanee ($\bar{x} = 13.3$ circuli; $n = 18$) ($t = 8.74$, $P < 0.05$).
- (2) The large kokanee spawning in Norns Creek are not recruited from local populations in the mainstem Columbia River or Lower Arrow Lake (i.e., Deer Creek spawners). The large Norns Creek spawners show significantly greater numbers of circuli than the 3+ age class from the upper Columbia River population in 1980 ($t = 13.06$; $P < 0.05$) and for the Lower Arrow Lake population in 1981 ($t = 10.12$; $P < 0.05$). Furthermore, the difference in scale character indicates that juvenile (i.e., age 2+) kokanee in the Columbia River in 1980 did not form the spawning population of large kokanee in Norns Creek (i.e., 3+ fish) in 1981.

Other differences in scale character support the conclusion that large Norns Creek kokanee are not recruited from the local populations sampled. Scales of mature Columbia River and Lower Arrow Lake kokanee exhibited very little resorption, while Norns Creek kokanee showed moderate to heavy resorption. Additionally, the wide spacing of circuli in the

Table 5. Scale characteristics of kokanee from various locations in the Columbia River system, 1980 and 1981.

Area of Capture	Time of Capture	Age at Capture	Sample Size	Number of Circuli to First Annulus			Degree of Resorption ^b	Spacing of Circuli in Third Year ^c
				Mean No.	S.D. ^a	Range		
Norris Cr. Large	fall 1981	3+	18	13.3	1.84	11-18	moderate to heavy	wide
Norris Cr. Small	fall 1981	3+	2	7.5	0.71	7-8	light	narrow to wide
Norris Cr. Large	fall 1980	3+	9	12.6	1.24	11-14	moderate to heavy	wide
Columbia R. (Km 49-56.2)	summer 1980	2+	20	6.8	0.69	5-8	-	-
Columbia R. (Km 49-56.2)	summer 1980	3+	20	6.9	1.02	5-9	absent to light	narrow
Deer Cr. (tributary to Arrow Lake)	fall 1981	3+	23	8.4	1.03	7-10	light	narrow
Lake Roosevelt	spring 1980	2+	3	9.6	0.58	9-10	-	-
Lake Roosevelt	winter 1979-80	3+	7	11.9	1.46	10-13	moderate	wide
Lake Roosevelt	spring 1980	3+	3	7.7	0.58	7-8	moderate	moderate
Columbia R. at Trail	fall 1981	3+	1	8.0			light to moderate	narrow

^a S.D. = standard deviation.

^b Vernon (1957) reported that the degree of resorption was similar within individuals of a population. The degree in this case is qualitative and based on a comparison of scales, with three variations (light, moderate, and heavy).

^c The spacing is qualitative and based on a comparison of scales, with three variations (narrow, moderate, and wide).

third year of all large Norns Creek kokanee, and relatively tight spacing of the corresponding circuli of local populations suggests different feeding habitats were utilized.

- (3) It is probable that large Norns Creek fish originate from a Lake Roosevelt kokanee population. This is based on the examination of the Lake Roosevelt scale samples.
 - Two populations of kokanee (i.e., large-sized and small-sized) appear to exist in Lake Roosevelt. Although the sample size is small, the kokanee scale samples provided by the U.S. Fish and Wildlife Service exhibit a positive relationship between length and the number of circuli present to the first annulus. The mean length of 3+ kokanee with scales containing less than 10 circuli to the first annulus ($\bar{x} = 381$; $n = 3$) is significantly less than the 3+ kokanee with at least 10 circuli present to the first annulus ($\bar{x} = 425$; $n = 7$) ($t = 2.56$; $P < 0.05$).
 - Comparison of the scale characters of these larger Lake Roosevelt kokanee (1976 year class) with those from large Norns Creek kokanee (1976 and 1977 year classes) reveals some similarity. There is no significant difference in the mean number of circuli to the first annulus between either year class of large Norns Creek kokanee and the large Lake Roosevelt kokanee (e.g., 1976 versus 1976 year classes, $t = 0.974$; $P > 0.05$). Furthermore, similar growth patterns (i.e., wide spacing of circuli) are apparent in the third year of many of the samples from the two areas.
- (4) Scale studies gave no conclusive evidence indicating the origin of the small Norns Creek kokanee. There is no significant difference in the mean number of circuli to the first annulus between the Norns Creek kokanee and (a) the Deer Creek kokanee ($t = 1.65$; $P > 0.05$); (b) the Columbia River kokanee ($t = 1.33$; $P > 0.05$); or (c) small Lake Roosevelt kokanee ($t = 0.33$; $P > 0.05$).

3.2.5 HEAVY METAL ANALYSIS

The results of analyses of mercury concentration in muscle tissue of kokanee from Norns Creek, the upper Columbia River near Norns Creek, and from Deer Creek (tributary to Lower Arrow Lake) (Appendix C) also support the conclusion that the larger Norns Creek kokanee originate from downstream areas. Of nine kokanee from Deer Creek analysed for muscle mercury concentration, one had a mercury level of 0.05 mg/kg (wet weight) while the remainder had levels below the detection limit (0.05 mg/kg). The mercury concentration in muscle from the five large sized kokanee from Norns Creek was considerably higher, averaging 0.12 mg/kg (range = 0.06-0.16 mg/kg). The single kokanee from the Columbia River had a muscle mercury concentration of 0.06 mg/kg.

Since the B.C. Waste Management Branch (unpublished data) has shown that heavy metal concentrations were significantly greater in fish sampled below Trail than in fish near Castlegar, the higher mercury concentrations in Norns Creek kokanee in comparison to kokanee from the Arrow Lakes Reservoir may indicate that the Norns Creek population (large individuals) originate from the downstream area. Analyses of additional samples of kokanee from the mainstem Columbia River above Castlegar (prior to the spawning period) would be necessary to verify this conclusion.

3.3 WALLEYE

Walleye, a species that is non-native to the Columbia River system, were introduced into Lake Roosevelt. It appears that, as the population expanded in Lake Roosevelt, walleye have extended their range to include portions of the Columbia River in Canada.

3.3.1 DISTRIBUTION AND ABUNDANCE

In the 1980 fall study only a few walleye were captured by the survey team, all between Castlegar and the Hugh Keenleyside Dam. However, walleye were reported taken throughout the study area by

anglers during the 1980-81 creel survey (B.C. Fish and Wildlife Branch 1981).

During the fall 1981 study period, walleye were abundant in the mainstem Columbia River within the study area. In the upstream sampling region walleye contributed 24.1% to the total gill net catch (Table 2). In the downstream sampling region they contributed 18.4% to the catch (Table 1). The apparent increase in abundance from fall 1980 to fall 1981 may reflect additional movement into the area.

Immature (sub-adult) walleye formed a large component of the sample. They contributed over 70% to the total catch of walleye in the downstream sampling region, suggesting an extensive rearing/feeding use of this area. In the upstream region immature fish were less abundant, contributing less than 25% to the total number of walleye captured. Young-of-the-year walleye were not captured in either region; however, their absence in the sample was most likely a result of the sampling gear (i.e., only gill nets) utilized.

3.3.2 MOVEMENTS

Walleye have been reported to undertake extensive seasonal movements (e.g., up to 380 km—Wolfert 1963). Information obtained during the fall 1981 study period documented possible extensive annual upstream movements by some walleye in the Columbia River system. One walleye, tagged in spring 1981 in the Spokane River, was recaptured in a gill net near Castlegar during fall 1981, a distance of approximately 150 km upstream. Another fish, tagged in the Spokane River in the spring of 1981, was recaptured in August 1981 by a local fisherman near Oasis (a distance of approximately 130 km upstream). The exact stimulus or purpose of these movements is unknown, but may be related to summer feeding activities.

3.3.3 SPAWNING

Suitable walleye spawning habitat is widely available throughout the Columbia and Kootenay rivers within the study area; however, no

specific spawning areas have been documented. Colby et al. (1979) state that spawning generally occurs at water temperatures between 5.6° and 11.1°C; thus, spawning in the study area would likely occur in the period April to May.

3.3.4 FEEDING HABITS

Cursory examination of stomach contents during the field investigations indicated that small fishes (e.g., redbside shiner, sculpin, sucker, and kokanee) were a major component of the diet of the walleye in the Columbia River. Invertebrates (primarily trichopterans) constituted a smaller component of the diet.

3.4 OTHER SPECIES

3.4.1 WHITE STURGEON

A substantial population of white sturgeon may be present in the Columbia River. A tag and release program conducted by the B.C. Fish and Wildlife Branch downstream of Trail in the spring of 1981 captured 94 sturgeon.

Four sturgeon were captured by gill net during the present study. Two individuals, weighing 2.3 and 2.5 kg, were captured in the downstream sampling region. A third white sturgeon was captured but not landed. The fourth individual, weighing approximately 18 kg, was captured 4.7 km below Hugh Keenleyside Dam.

The nature and timing of white sturgeon movements in the study area are unknown. Haynes et al. (1978) reported that larger white sturgeon in the Columbia River, between Priest Rapids and McNary Reservoir (Washington), moved upstream in summer and fall, while the smaller individuals moved downstream during this period. Similar movements between size classes may occur for this area of the Columbia River.

3.4.2 RAINBOW TROUT

Rainbow trout were absent from fall 1981 gill net catches in the upstream sampling region and exhibited a low abundance in catches from the downstream region (Appendix A, Tables A-2 and A-3). This is similar to the abundance of this species recorded during the fall 1980 sampling in these areas.

Three additional tag returns were received from rainbow trout marked in spring 1981 studies. These, plus prior returns, produced a 12% tag recovery rate for the 109 rainbow trout specimens marked in Norns and Champion creeks. Movements exhibited by the three recent returns support the movement patterns suggested for this species from previous tag returns (i.e., a downstream movement from spawning areas to summer feeding or overwintering areas). All three individuals were recaptured downstream from the release point—one near Oasis (Km 24.0), one near the mouth of the Kootenay River (Km 45.0), and one approximately 156 km downstream of Norns Creek, in a tributary to Lake Roosevelt (Hawk Creek).

3.4.3 MOUNTAIN WHITEFISH

Mountain whitefish were abundant in the Columbia River during the fall 1981 study period, contributing 29.9% to the gill net catch in the upstream sampling region and 30.3% to the gill net catch in the downstream sampling region.

During the fall 1980 survey between Castlegar (Km 48) and Hugh Keenleyside Dam (Km 56.2), only 5% ($n = 49$) of the mountain whitefish captured were mature adults. During the fall 1981 survey of the same region, 100% ($n = 26$) of the fish captured were adults. Similarly, 95% ($n = 55$) of the mountain whitefish captured and examined for maturity in the downstream sampling region were adults. The apparent variation in the age class composition of the catch above Castlegar between 1980 and 1981 is probably attributable to changes in sampling technique (i.e., mainly electrofishing in 1980 and gillnetting in 1981).

3.4.4 OTHER SPECIES

Other minor species of coarse fish sampled during this study are not discussed in detail in this report. Gill net catches in the mainstem indicated an abundance of other species similar to those found during the fall 1980 study period. Sampling results for these miscellaneous species are presented in Tables 1 and 2 and Appendix A.

4.0 EFFECT OF DEVELOPMENT

At the present time, fish movements in the Columbia River are unrestricted from the Grand Coulee Dam (Lake Roosevelt) upstream to the Hugh Keenleyside Dam and in the Kootenay River upstream to the Brilliant Dam. Studies conducted in 1980 and 1981 indicate that a number of sport fish species, including kokanee, rainbow trout, and walleye, appear to undertake spawning migrations or other distinct seasonal movements past the proposed Murphy Creek damsite on the Columbia River.

Results of the fall 1981 studies and interpretation of scale, age, and growth characteristics of kokanee suggest that spawning escape-ments to Norns Creek, and probably some upstream regions of the mainstem Columbia River, originate downstream. During 1980 sampling in the mainstem Columbia River between Castlegar and Hugh Keenleyside Dam, a large number of kokanee were marked. Most of these fish were 2-year-olds, therefore, many would have spawned in fall 1981. However, no marked kokanee were observed in the Norns Creek spawning run, indicating that these spawners originated from other populations, outside the study area. Since there are no known populations of kokanee that rear upstream of their natal stream (H. Andrusak, pers. comm.), it is likely that the Norns Creek spawners originated in Lake Roosevelt, approximately 85 km downstream. Without suitable mitigative measures to ensure upstream passage and access to existing or alternative spawning areas, the Norns Creek kokanee run, and probably significant numbers of kokanee spawning in the mainstem Columbia River in the study area, would be lost. Provision of fish passage facilities does not guarantee the maintenance of this run since numerous other factors, including the amount of suitable spawning area remaining and survival of fry during downstream migration through the reservoir, must be considered. Also, the high pre-spawning mortality observed in 1981, if caused by a bacterial infection such as *C. columnaris*, may be even more severe after construction of a dam because of additional stress-related factors. For example, in the lower Columbia River, congestion of fish,

such as occurs at fishways, has been shown to be an important factor influencing the impact of this disease on fish populations (Pacha and Ordal 1970).

Tagging studies initiated during the spring of 1981 have shown that a large segment of the rainbow trout population spawning in Norns and Champion creeks undertakes post-spawning movements to areas of the Columbia River below the proposed damsite, with some moving downstream presumably into Lake Roosevelt. The Murphy Creek dam would be expected to severely affect rainbow trout populations in the study area by blocking upstream spawning migrations to tributary streams and interfering with other seasonal movements.

Increases in the abundance of walleye in the study area, and captures of walleye near Castlegar and Trail that had been tagged in Lake Roosevelt, indicate that this species undertakes extensive upstream movements in the Columbia River. Although spawning areas may exist, the upstream regions appear to be increasingly utilized as feeding/rearing habitat. A dam on the Columbia River at Murphy Creek would interfere with seasonal movements of this species.

Other species that may undertake movements past the proposed damsite include chinook salmon, white sturgeon, carp, and Dolly Varden. Information on movement patterns of these species is sparse, but chinook salmon, stocked in Lake Roosevelt, have been captured by anglers in the study area. Carp and Dolly Varden are both reported to spawn in the study area.

It is apparent from the available data that important seasonal movements of sport fish occur past the proposed Murphy Creek damsite, with some migrations apparently originating as far downstream as Lake Roosevelt. Significant impacts on sport fish can be expected unless suitable mitigative measures are implemented in the design and operation of the project.

5.0 PLATES





Plate 1. Looking downstream at trap net sites on the mainstem Columbia River. 19 August 1981. Trap on the far side of the river is completely submerged and only the float is visible.



Plate 2. Trap net site (on left downstream bank) following overnight drop in water level. 20 August 1981. Fluctuations in water level decreased trap net efficiency.

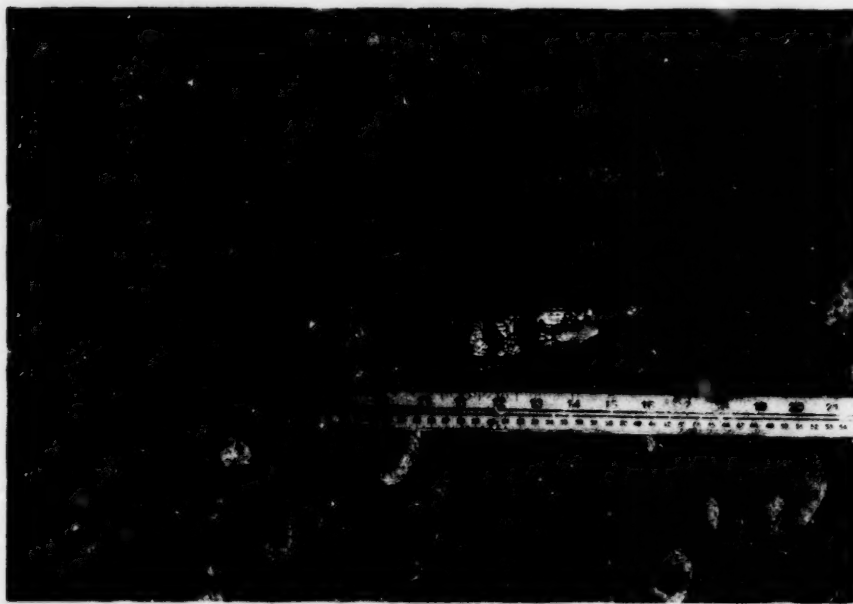


Plate 3. A large female kokanee found dead in Norns Creek (Km 1.1) on 25 August 1981. This individual had not spawned. Note the extreme body lesions and infection.



Plate 4. Kokanee spawners in Norns Creek (Km 1.23). Lighter coloured areas of stream substrate are areas of redd construction. 28 August 1981.

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Appendix A

SUMMARY OF FISH CAPTURES AND CUE,
COLUMBIA RIVER, FALL 1981

Table A-1. Gill net catch and CUE (No. fish/100 m²·24 h), Columbia River downstream sample region, 15 August to 6 September 1981.

Station (km)	Date Set	Duration of Set (h)	Net Area ^a (m ²)	Number and CUE													
				K	RT	OV	PZ	LM	YU	LMS	LSS	LINC	MSF	PN	WSI	Total	
GN 7 (8.6)	16 Aug.	12.7	144		7					1							9
	18 Aug.	105.7	144		9.2			8	2	3				1.3			13.8
	4 Sept.	13.5	144					1.1	0.1	0.5		9		0.0			26
	Total	131.9	144		7			9	2	3		9		1.2			46
GN 8 (7.6)	19 Aug.	12.0	72		0.9			1.0	0.1	0.5		1.1		0.8			4.5
	20 Aug.	65.5	72					2	5.6	11		13.9					28
	Total	77.5	72		0.9			3	6.7	12.1		15.0					33
	GN 9 (8.9)	22 Aug.	35.0	144		1	1		1.2	7.3	0.6		4.6				
26 Aug.		23.5	144		0.5	0.5		16.2	1.0	6.2		6.2	0.5				80
28 Aug.		10.5	144					14	2	6		1					26
29 Aug.		10.0	144					9.9	1.4	4.3		0.7					18.4
30 Aug.		10.0	144														0
31 Aug.		10.0	144		1	1.7		5.0	1.7	5.0		1.7					11.7
Total		99.0	144		2.5	2.2		32.3	11.6	22.6		12.2					128.3
GN 10 (8.0)	22 Aug.	120.0	72		0.2	0.1	0.2	0.9	0.3	1.0		2.7	0.2	2.0	0.2		21.5
	1 Sept.	95.0	144		1	2	1	2.2	1.9	2		0.1					33
	Total	215.0	144		0.2	2.1	1.2	3.1	3.8	3.0		2.8	0.2	2.0	0.2		54.8
	Totals	503.4			2	11	2	79	4	48	23	34	1	8	46	3	261

^a Nets composed of 16 m² panels (15 m long x 2.4 m deep) of 3.8, 6.4, 8.9, and 11.4 stretched mesh.

Table A-2. Gill net catch and CUE (No. fish/100 m²·24 h), Columbia River upstream sample region.
15 August to 6 September 1981.

Station (km)	Date Set	Duration of Set (h)	Net Area ^a (m ²)	Number and CUE									
				K	DV	MW	LW	YW	LNS	BLS	LSS	LING	NSF WST Total
GN 3 (47.5)	24 Aug.	18.5	144	1 0.9			1 0.9	4 3.6			4 3.6	3 2.7	13 11.7
GN 4 (54.2)	24 Aug.	17.5	144	1 1.0									1 1.0
	25 Aug.	16.0	144	1 1.0	2 2.1	8 8.3		5 5.2	2 2.1		1 1.0	4 4.2	23 24.0
Total				2 1.0	2 1.0	8 4.0		5 2.5	2 1.0		1 0.5	4 2.0	24 11.9
GN 11 (51.5)	4 Sept.	45.0	108			18 8.9	2 1.0	12 5.9		1 0.5	7 3.5	9 4.4	1 0.5 50 24.7
Total				3	2	26	3	21	2	1	12	9	7 1 87

Table A-3. Trap net catch, Columbia River. 17 August to 1 September 1981.

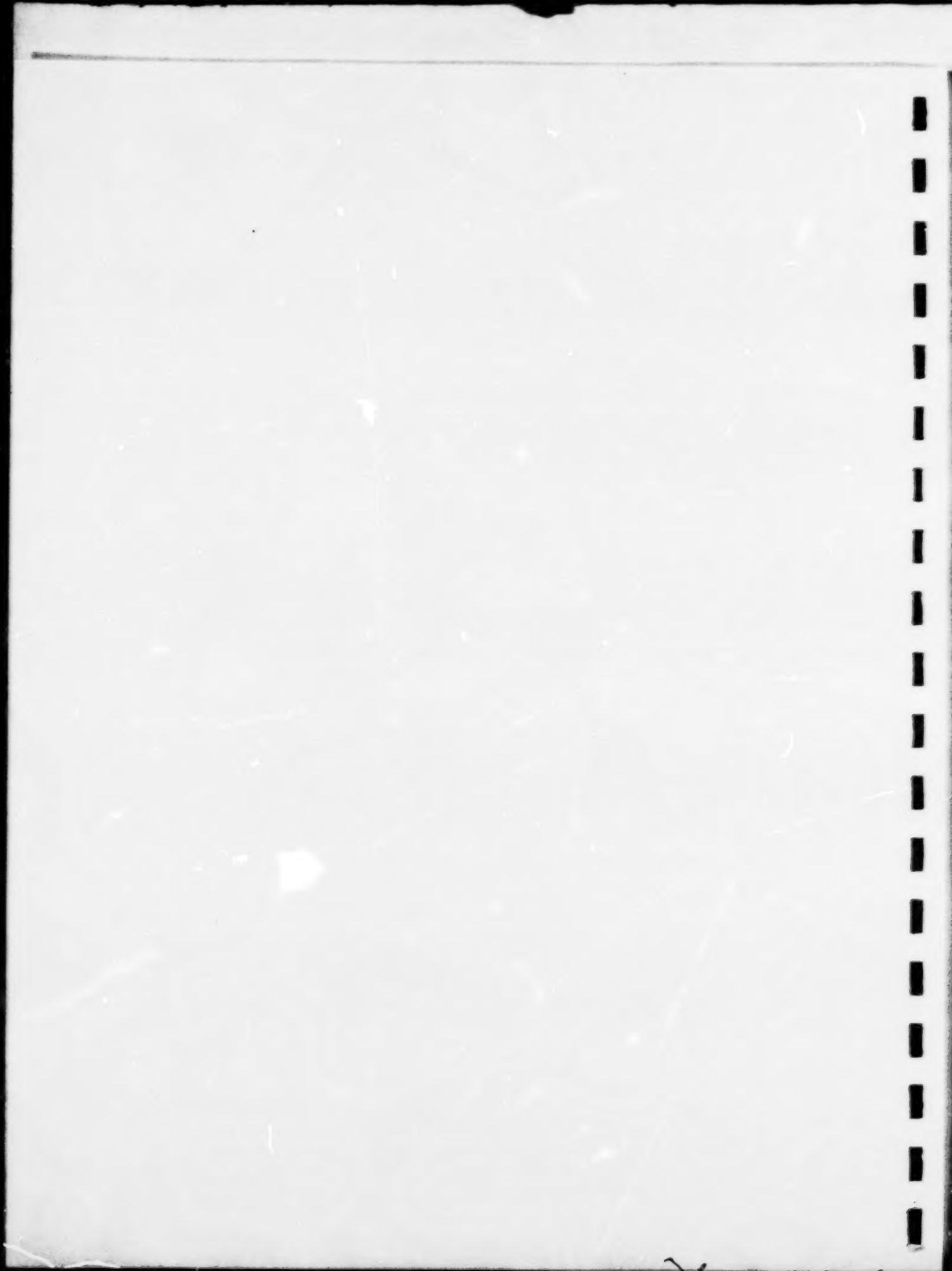
Station (km)	Date Set	Duration (days)	Number			
			MW	RT	NSF	Total
T4 (8.5)	17 Aug.	14.6			2	2
T3 (8.1)	17 Aug.	18.8	1	1	1	3
Total		33.4	1	1	3	5

Table A-4. Float survey summary, Columbia River and Kootenay River. 1981.

Location (km)	Date	Surveyed Distance (km)	Side of Channel Surveyed	Approximate Number Observed								Total
				RT	DV	MW	PM	NSF	YW	Suckers ^a	Carp	
Kootenay R. (1.6-0)	2 Sept.	1.6	right			50				150		200
Columbia R. (8.6-4.5)	3 Sept.	4.1	left	1		100	100	60	45	375		681
Columbia R. (8.1-6.0)	3 Sept.	1.9	right		1	75				100	40	216

^aNot identified to species.

Appendix B
SUMMARY OF TAGGING STUDIES,
COLUMBIA RIVER, FALL 1981



B.1. TAGGING STUDIES

During the fall 1981 field investigations, 112 fish captured in the mainstem Columbia River were tagged and released (Table B-1). Eighty-nine fish were tagged and released in the downstream sample region and 23 in the upstream sample region. There were no recaptures of fish tagged in either of these regions during the study.

Table B-1. Summary of fish tagged in the mainstem Columbia River. 15 August to 6 September 1981.

Species	Number Tagged		Total
	Downstream Sample Region	Upstream Sample Region	
Dolly Varden		1	1
Mountain whitefish	14	10	24
Lake whitefish	2	1	3
Walleye	17		17
Largescale sucker	19	8	27
Longnose sucker	15	2	17
Northern squawfish	4		4
Peamouth	16		16
White sturgeon	2	1	3
Total	89	23	112

Appendix C

KOKANEE TISSUE MERCURY CONCENTRATIONS



Table C-1. Mercury concentration in muscle tissue from kokanee from the Columbia River, Norns Creek, and Deer Creek, August - September 1981 (chemical analysis conducted by B.C. Ministry of Environment).

Sample No.	Location	Date	Length	Weight	Hg Concentration mg/kg Wet Weight
M1838	Columbia River Km 47.5	25/09/81	470	1520	0.06
M1843	Norns Creek	25/09/81	508	1480	0.06
M1863	Norns Creek	26/09/81	494	1400	0.16
M1864	Norns Creek	26/09/81	474	1450	0.11
M1865	Norns Creek	26/09/81	509	1900	0.10
M1866	Norns Creek	26/09/81	488	1300	0.15
M1956	Deer Creek	02/10/81	221	110	L 0.05 ^a
M1957	Deer Creek	02/10/81	234	130	L 0.05
M1958	Deer Creek	02/10/81	217	100	L 0.05
M1959	Deer Creek	02/10/81	224	170	L 0.05
M1960	Deer Creek	02/10/81	220	120	L 0.05
M1961	Deer Creek	02/10/81	239	140	L 0.05
M1962	Deer Creek	02/10/81	218	110	L 0.05
M1963	Deer Creek	02/10/81	260	220	L 0.05
M1964	Deer Creek	02/10/81	239	150	0.05

^a L = less than

Appendix D
TERMS OF REFERENCE

TERMS OF REFERENCEA. Inventory

1. Determine, by means of trap nets in the Columbia River near the Pend D'Oreille River, whether kokanee or other sport fish species migrate upstream past the damsite.
2. If a kokanee migration exists, tag a subsample of the run with Floy anchor tags or similar device.
3. Enumerate kokanee spawning in Norns Creek and determine what proportions of large and small kokanee carrytags.
4. Collect additional biological information where possible.

B. Effect of Development

1. Interpret the results relative to the proposed project and post project fishery.
2. Comment on probable source(s) of kokanee spawning in Norns Creek.

C. Prepare a report detailing methods, results and conclusions.

POOR

QUALITY

ORIGINAL